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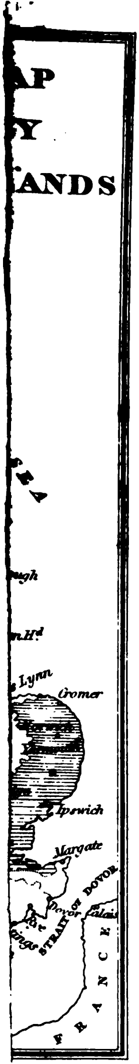
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THE

ELEMENTS

OF

PRACTICAL GEOLOGY

AS APPLICABLE TO

MINING, ENGINEERING, ARCHITECTURE, &c.;

WITH NOTICES OF THE

MINES AND MINERAL PRODUCTIONS

OF

GREAT BRITAIN.

ILLUSTRATED BY PLATES AND WOOD-CUTS.

BEING A SECOND EDITION, GREATLY IMPROVED AND ENLARGED,

OF THE

"INTRODUCTION TO THE STUDY OF GEOLOGY."

By FREDERICK BURR.

"A knowledge of our subterranean wealth would be the means of furnishing greater opulence the country than the acquisition of the mines of Mexico or Peru."—SIR J. SINCLAIR.

LONDON:
WHITTAKER AND CO., AVE-MARIA LANE,
AND J. AND C. WALKER, 9, CASTLE STREET, HOLBORN.

1838.

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PREFACE.

In the introduction to the little work upon which the present volume is founded, it was observed that, "the great and increasing interest which is at the present time evinced for the study of Geology, and the manner in which this science is beginning to connect itself with the pursuits of the Miner and Engineer, will probably be deemed a sufficient apology for any work, having for its purpose to facilitate the acquisition of this branch of knowledge." The correctness of this view has been fully confirmed by the favourable reception of the work in question, and the early demand for a second edition.

It has in the present volume been the object of the writer, to explain as briefly and simply as possible, the leading principles of Geology, to point out their application to the internal structure of this country, and the connexion of this structure with various facts of general interest and importance. In accomplishing this, he has endeavoured to render available the local knowledge and the small amount of geological information which most persons may be presumed to possess. It has also been his object to render intelligible and generally useful, the immense mass of information contained in the beautiful and accurate geological maps of our own country, which have been published by different individuals, and which may be said to contain the most valuable summary of the labours of English Geologists.

In an elementary work, novelty can hardly be expected; but it may be observed that a long and practical acquaintance with nearly all the phenomena described, together with the habit of viewing them with relation to purposes of utility, as well as in connexion with science, have prevented this Introduction from being a mere compilation from the labours of others, and given it as much originality as the nature of the subject allowed.

Having had numerous opportunities of observing the wants of practical men, and the difficulties which impede the more general cultivation of geological science, the plan of the present work has been arranged with a view as far as possible to supply the former, and to obviate the latter.

The first part it will be seen is entirely devoted to those preliminary views of the constitution of the globe, a previous acquaintance with which is absolutely essential to any sound progress in geological science.

In the second part the elementary facts and principles of geology are explained at considerable length, and illustrated in such a manner as to render them readily intelligible to the ordinary reader.

The third part embraces descriptive geology, and includes a comprehensive view of the internal structure of Great Britain, with such brief reference to foreign localities as was deemed consistent with the general plan of the work.

Although the practical applications of geology have been repeatedly glanced at and illustrated in the former portion of the volume, the fourth and concluding part has been entirely devoted to this important subject, which is there more fully developed under its appropriate heads.

The Appendix contains some additional explanation of the plates, an explanation of the terms most frequently used in geology, and a tabular view of the mineral statistics of Great Britain, which, although necessarily formed upon imperfect data, may still be regarded as a useful approximation.

As the result of many years' devotion to a favourite science, and of extensive observation both practical and theoretical, of mineral phenomena, it is hoped that the "Elements of Practical Geology" may prove a useful manual to the numerous class o readers for whom it is more especially intended.

John's Terrace, Hackney Road,
October, 1838.

E. S. Popper,
New York

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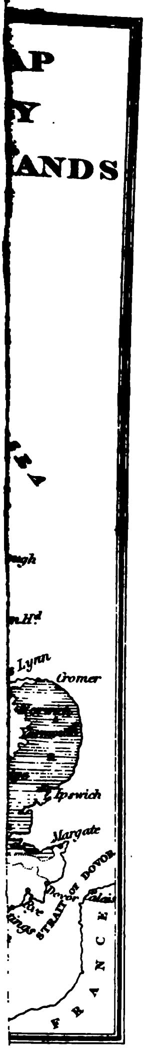
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water which descends from the atmosphere, and finally discharging it into the sea. Thus, by evaporation from the sea, and condensation in the atmosphere, a constant interchange and alternation is kept up, between the aqueous ocean beneath us, and the aerial ocean above; and, as we shall hereafter have occasion to observe, the solid materials of the globe experience very important changes, in consequence of this action, although of a nature so gradual, that to the ordinary observer they are almost imperceptible.

PHYSICAL GEOGRAPHY.

Subjects to be considered.—Having thus noticed the figure of the earth, and the general disposition of the materials of which it is constituted, there are some few particulars connected with its physical geography, which will next require attention. These are principally the configuration of the land—the elevation and structure of hills and mountain masses—the composition of the ocean, and form of its bed—the distribution of heat, both upon the earth's surface and below it—and, a subject which is closely connected with the former, the distribution of plants and animals.

Distribution of land and water.—As regards the distribution of the land and water, there is but little indication of order and regularity. The ocean may properly be considered to extend over the whole globe, the land appearing at a greater or less elevation above it, in patches of every imaginable size and contour, from the smallest rock or island, to the largest continent. It has been estimated that the area of the water is to that of the land nearly as two to one, or, more correctly, as seven to three, more than two-thirds of the earth's surface being thus covered with water, while less than the remaining third consists of land.

The position of the great masses of land constituting our continents, differs greatly in the eastern and western hemispheres; in the former it is nearly east and west, or parallel to the equator, in the latter, on the contrary, it is nearly north and south, the land stretching almost from pole to pole. It is remarkable, that in both hemispheres the poles are situated in the ocean, and that, if we compare the northern with the southern, the antipodes of the land, with scarcely an exception, will be water, and of course *vice versâ*.

ELEVATION OF THE LAND.—On considering the elevation of the land above the ocean, it will be found that a large portion of it is very slightly raised, more especially upon the banks of great rivers, and along the sea-shore. On the continent of Europe, this is the case with Holland, northern Germany, and a large portion of Russia; and on the continent of America, there are similar low and extensive plains around some parts of the coast, adjoining the mouths and course of the great rivers.

It is scarcely necessary to observe, that the elevation of hills and mountains presents every possible gradation from the most trivial eminences to the towering masses of the Himalaya mountains, which have an elevation of more than five miles perpendicular above the level of the sea. In our own country the highest summits range in a line approaching north and south, and extending from the Highlands of Scotland, through Cumberland, Westmoreland, and Lancashire, into Wales, and finally terminating in the elevated region of Dartmoor in Devonshire. The following are the elevations of the principal points upon this range, which it will be observed exhibit a progressive increase as we proceed northward. Dartmoor attains the height of nearly 1800 feet, the Beacons of Brecknock, in south Wales, are 2,862, Plynlimmon is 2,463, Cader Idris and Arran Mowddy are respectively 2,914 and 2,955 feet above the sea-level, while Snowdon, the highest of the Welsh mountains, rises to the height of 3,571 feet. In the north of England the highest summits are those of Cross Fell and Helvellin, elevated 2,900 and 3,055 feet above the sea. In Scotland the mountains attain a still greater elevation, several rising to the height of between 3,000 and 4,000 feet, and Ben Nevis, which is considered the highest mountain in Great Britain, is 4,365 feet in height.

The most remarkable feature in the physical geography of Great Britain is, therefore, a range of elevated ground, stretching from north to south, and prevailing over the western portion of the country. Although, eastward of this commanding range, the country is much diversified by hill and dale, there are few hills which exceed a thousand feet in height, while in many parts, as in Essex, Norfolk, Suffolk, Cambridgeshire, Bedfordshire, and Lincolnshire, there are extensive tracts of nearly level country.

Ireland is in its central portion a flat or gently undulated country, but it has in some parts very bold mountain-ranges, more especially around the coast, as in Londonderry, Wicklow, Downshire, and Kerry. The highest mountains in Ireland are Macgillicuddy's Reeks, in the latter county, elevated 3,405 feet above the sea.

On the continent of Europe the most elevated mountain is well known to be the snow-capped summit of Mont Blanc, which forms the highest point of the Alps, and rises 15,660 feet above the sea. There are summits in the Pyrenees which have an elevation of about 11,000 feet, and the volcanic cone of Etna is equally lofty.

In Africa the highest mountains are supposed to be those of Geesh in Abyssinia, elevated about 15,000 feet; but the loftiest summits in the world are those of the Himalaya mountains in Asia, which separate India from Thibet. The highest peak of this range is Dhwalagiri, and the elevation, though not very accurately known, is estimated at about 28,000 feet.

On the continent of America the highest points are those of the Andes, Chimborazo being elevated 21,425 feet, while several other peaks of this range are almost equally lofty. North of the equator the mountains are not so high; the volcano of Popocatepetl, which forms part of the range of the Cordilleras, in Mexico, rises to the height of 17,720 feet, and the Rocky mountains, which form the prolongation of this immense chain through the northern part of the American continent, are not supposed to rise more than from 12,000 to 13,000 feet above the sea level.

The elevation of mountains forms little subject for general remark, other than that it appears to bear some relation to the magnitude of the continents in which they are situated; thus, the highest mountains occur in the vast continent of Asia, less elevated masses occur in the smaller continent of Africa, and in the continent of America, which is of intermediate size, the mountains have also an intermediate elevation. In Australia, which may be regarded as the smallest of our continents, the mountains appear to be still less elevated.

EXTERNAL STRUCTURE OF HILLS AND MOUNTAINS.—The external structure and configuration of hills and mountains forms a curious and interesting, although hitherto neglected, branch of geological inquiry. These elevations have been shown to perform an important function in the economy of nature, by collecting and duly distributing over the earth's surface the waters derived from the atmosphere; and, to fit them for this office, a suitable structure has been given—a structure which is infinitely varied according to the nature and composition of the mass. The more perfect representation of the undulations of the surface in modern maps, and more especially in those constructed for military purposes, will, however, in time, throw much light upon this subject, and more firmly establish those principles of which, at present, we have only a vague and general idea.

The structure both of hills and mountains is formed upon the same general plan, but greatly modified according to an infinite variety of circumstances. Mountains and hills, as must be well known, do not by any means form isolated and unconnected masses. The isolated peaks which rise from them, prominent as they are from their commanding situation, form but a small and inconsiderable portion of their mass. Mountains and hills mostly occur in chains or ranges, having a definite direction, a considerable length, and a narrower, but still considerable breadth. From the more elevated central portion, which, more especially in volcanic mountains, is generally characterised by the irregular occurrence of abrupt and lofty peaks, smaller ranges, or branches, are thrown out into the surrounding low country, and these have again other minor branches and outliers connected with them, the whole enclosing a regular and continuous system of valleys. It rarely happens that both sides of a hill or mountain have the same degree of steepness or inclination; on one side there is generally an abrupt escarpment, and on the other a gradual slope, so that the general profile of any range, taken across the line of its direction, would present the figure of a wedge-like mass, or a series of wedge-like masses, a circumstance occasioned in great measure by peculiarities of internal structure, which will hereafter be noticed.

As regards the direction of elevated ranges of ground, there is generally one or more extending through every continent and island, and thus determining its general form and configuration. The mountains of Great Britain, previously noticed, present an example of this kind, and a still more striking one is afforded by the vast chain of mountains which traverses the whole continent of America. Mountains and hilly ranges are not unfrequently parallel to each other; and, when viewed on the great scale, they often enclose vast tracts of country within an irregularly-curved area.

The figure of hills and mountains, as dependent on their composition and internal structure, will be noticed in the body of this work; but it may here be observed, that the subject is well deserving of attention, both from the civil and military engineer, as, both in the formation of roads, canals, railways, and other public works, and the operations of an army in the field, this circumstance forms a most important element for their consideration.

Composition of the ocean.—We have next to direct our attention to the vast fluid covering of the ocean, which spreads over so large a portion of the globe—chiefly to its composition and the form of its bed. The water of the sea is distinguished from that which occurs in lakes or rivers, or which generally issues from springs, by its greater impregnation with earthy and alkaline substances, and more especially by its large proportion of muriate of soda, or common salt, which amounts, on an average, to about 3 per cent.; sulphate of soda, and the muriates of lime and magnesia, are also present, the total quantity of saline matter held in solution by the ocean thus amounting to from 3½ to 4 per cent., which raises its specific gravity to 1,028, that of distilled water being 1,000. The water of the ocean is, therefore, a very compound fluid; and, as aqueous action has, at a former period, acted most extensively, both chemically and mechanically, upon the surface of the globe, its properties and nature are interesting subjects of inquiry. Besides the matter which is thus held in solution, by the waters of the ocean, there is also a large quantity of sand, or finely comminuted mineral substance, which is constantly in a state of mechanical suspension in certain situations, as around the mouths of great rivers, and on some parts of coasts. This sedimentary matter is of course in a constant state of deposition, as will be hereafter noticed; while, under favourable circumstances, chemical deposition may also take place, either from the ocean, from lakes, or springs.

FORM OF ITS BED.—The form of the bed in which the ocean is collected, spreading as it does over so large a portion of the earth's surface, is a subject of much interest; large portions of this bed have been proved by soundings to be comparatively shallow, thus corresponding with the small elevation of much of the land, and its most profound abysses appear to follow certain known lines and centres, thus offering a counterpart to mountain ranges and summits. The depth of these is of course very uncertain, but from various considerations it is not generally supposed to exceed ten miles, and, in all probability, it is seldom more than half that distance. We thus arrive at the general conclusion, that the large portion of the earth's surface which lies beneath the ocean possesses the same general structure as that which is elevated above it.

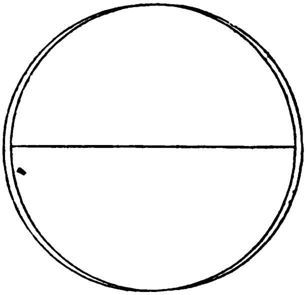
DISTRIBUTION OF HEAT—CLIMATE.—The distribution of heat, both upon and within the earth's surface, and the influence of temperature and climate, both upon the animal and vegetable kingdoms, are inquiries of much importance to the geologist, as it is only by a correct knowledge of these circumstances that he is enabled to explain many of the important phenomena which meet his view, when he begins to examine into the relations and origin of those materials of which the crust of the globe is composed, and to investigate the organic reliquiæ of past ages which they enclose.

The actual quantity of heat received by the earth's surface is entirely due to the solar influence, but its distribution depends on a great variety of causes. Were the earth's surface a truly spheroidal and homogeneous mass, its temperature would decrease from the equator to the poles, according to a fixed and regular progression. Under the existing circumstances of the earth's surface, this law of decreasing temperature obtains, in so far, that the temperature is greatest at the equator, and least at the poles, but the ratio in which it diminishes is subject to great and striking anomalies, and very different climates are often experienced under the same latitude. The causes of these anomalies are to be found in the different absorbing and radiating powers of the land and ocean, and also in the rapid diminution of temperature which takes place in the higher regions of the atmosphere, into which the more elevated ranges of mountains frequently ascend.

The influence of the ocean upon climate is very great, as, from the peculiar constitution of water, with reference to temperature and density, the temperature of the sea is extremely equable, and, through the medium of the winds which are constantly passing over it, this equable temperature is in some measure communicated to islands and the coasts of continents. To explain this action, it may be observed, that, when a current of air passes over the sea, which is hotter than itself, it becomes cooled by the consequent evaporation, while one which is colder of course becomes warmer by contact with the ocean. The climate of our own insular country is greatly influenced by this cause, and we neither experience the same extremes of heat or of cold which are felt under the same latitude, both on the continent of Europe and America, as, for example, in portions of Russia and Canada.

The second great cause which influences climate, and the only other which need here be noticed, is elevation above the sea-level. The heat which the earth receives from the sun is radiated again into the atmosphere, and most powerfully, of course, at the equator, where that heat is the greatest. The effect of this radiation is most sensible in the lower portion of the atmosphere, but it rapidly decreases as we ascend upwards, till the upper regions become exceedingly cold. Even at the equator, the temperature of the atmosphere falls to the freezing point at an elevation of from 15,000 to 16,000 feet, or about three miles above the level of the sea. As the amount of radiation from the earth gradually decreases from the equator to the poles, the point of congelation has a less and less elevation in proportion to the latitude, till towards the poles it actually coincides with the earth's surface, thus forming a concentric spheroid, as shown in the annexed figure.

Fig. 1.



Mountains, whose summits rise above this external spheroid, or *curve of congelation*, are of course covered with perpetual snow, and this height depends entirely upon the latitude. According to the calculations of the late Sir John Leslie, the height of this curve, at the equator, is 15,207 feet, while, in the mean latitude of Great Britain, it is only about 5,000 feet, or one mile.

It will thus be seen that climate is greatly dependent on elevation, of which one of the most striking examples is to be found in the lofty Himalayan range. The summits of these mountains, although in the latitude of 28° to 30°, are covered with everlasting snows, while the plains and valleys beneath them display all the unfading verdure of a tropical climate; and every gradation, between the two extremes, is to be found in the intermediate slopes and elevated plains by which they are surrounded. Were some of the mountains of our own country rather more elevated, their summits would enter within the curve of congelation, and thus be covered with perpetual snow. The diminution of temperature, which is experienced on rising to a sufficient elevation to approach this point, must have been observed by all who have ascended the mountains of Wales, or the north of England, where, even in the midst of summer, a sensible degree of cold will always be found to prevail.

INTERNAL TEMPERATURE OF THE EARTH.—We have next to consider a point of great geological interest—the distribution of heat beneath the earth's surface, or the temperature of the internal mass of the globe. The heat of the earth's surface, being entirely derived from the sun, passes off again by radiation into the atmosphere, and, by conduction, into the solid mass of the globe. The nature and extent of the radiation into the atmosphere has already been considered, but the latter subject of inquiry is not perhaps quite so satisfactorily ascertained. It is certain, however, that the solar influence does not penetrate to any considerable depth below the surface, and about 100 feet is generally considered as its limit. It is, therefore, entirely a matter of observation and experiment, whether below this limit the temperature of the globe is invariably the same or not.

A circumstance, which has long been known to miners, bears most materially upon this point—that the interior of deep mines is much warmer than the surface; and also, that, as the workings are carried to a greater depth, the temperature becomes proportionally higher. For a long period, however, a vague and general explanation of this phenomenon was deemed sufficient; it was supposed to arise entirely from the animal heat of the miners, from the lamps or candles by which their occupation is carried on, the want of ventilation, and similar local and partial causes.

This explanation, although at first sight very plausible, and in fact long regarded as satisfactory, will not, however, bear the test of rigid examination, for not only has the atmosphere of mines a high temperature in proportion to their depth, but the rock itself in which the excavations are formed, and the water which issues abundantly from it (often several hundred gallons per minute), have a temperature quite as elevated, or in some cases even more elevated still. Nor is this phenomenon of a high internal temperature, of rare and partial occurrence only; it prevails alike in England, in France, in Germany, in Mexico—in fact, in every part of the globe where deep mines have been opened, and it is manifested also in the temperature of deep Artesian wells, and of hot springs, which appear in fact to be nothing more than waters issuing through some crack or fissure from the more deeply-seated portions of the earth's crust. It amounts, therefore, to a certainty, both from the heat of the *solid rock* and that of the water and air in contact with it (far beyond what could be communicated by local causes), that the interior of the globe has a temperature of its own independent of the solar influence; and it appears, from experiments made in various parts of the world below the *invariable plane*, or that point where the solar influence terminates, that this increase of temperature amounts to about 1° Fahr. for every eight or ten fathoms,* and we are therefore warranted in believing that the materials of the globe may even be in a state of incandescence at a depth short of a hundred miles, measured perpendicularly from the surface. The phenomena of earthquakes and volcanoes, together with many others hereafter to be noticed, appear to be closely connected with the heated state of the earth's internal mass.

INFLUENCE OF CLIMATE UPON THE ANIMAL AND VEGETABLE KINGDOMS.—The influence of temperature and climate upon the animal and vegetable kingdoms is the next subject which requires our attention, and this influence is of so marked and decided a character, as to require but little explanation or remark. Although every temperature and climate may be considered as congenial to its appropriate races of the animal and vegetable kingdom, it is only in the high temperature of tropical climates that either attain their maximum development. We thus find in the torrid zone birds of the largest size and gayest plumage; the largest and most powerful reptiles, as the crocodile and gavial; quadrupeds of surpassing size and strength, as the lion, the tiger, the leopard, the elephant, the rhinoceros, and the cameleopard. The ocean is in tropical climates alike distinguished by the production of corals, shells, and fishes, peculiar to hot regions; and the prodigious accumulation of submarine zoophytes there attains a vast importance, elsewhere unknown. The vegetable productions of tropical climates are equally distinguished for their luxuriance and variety: the palm, the arborescent fern, the sugar-cane, the coffee-tree, with innumerable others, exhibit the most luxuriant types of vegetable life, and afford the richest fruits and spices. In the temperate zone, as Great Britain for example, this luxuriance entirely disappears, and both animal and vegetable existence appear in less variety, and in comparatively diminutive forms; while on approaching the polar circles we are struck with the scantiness of animated creation, which is there chiefly represented by the rein-deer and the polar bear upon the land, and the whale in the ocean, while a few mosses and lichens compose the trivial vegetation of the frozen surface. Our present concern is, however, rather to call obvious facts distinctly to mind, than to enter into any details of them; we here, therefore, leave the subject, which, as will be seen hereafter, is one of great importance in a geological point of view, since the earth has been inhabited by many successive races of animals, and clothed with successive mantles of vegetation, the reliquiæ of which are beautifully and perfectly preserved for our examination in a fossil state.

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* In some of the deep mines of Cornwall I have found the temperature increase very regularly in the latter ratio, or 1° Fahr. for every ten fathoms perpendicular depth; in other cases the increase of temperature has been still more rapid.

ITS CONNEXION WITH GEOLOGY.—As these fossil forms, although differing from, are still very analagous to, the races which now exist, they throw considerable light upon the state of the earth's surface in periods of high geological antiquity, they indicate the ancient distribution of land and water, and point out with precision the conditions of temperature and climate (often widely differing from those of the present time) which must have prevailed at the period of their existence. Zoology and botany thus contribute valuable aid to geology, while they receive in return a most important supplementary addition to the existing types of animal and vegetable life by the unlooked-for discovery and restoration of those extinct races which belonged to the earlier history of our planet, and which perished amidst its ancient convulsions.

CHEMICAL CONSTITUTION OF THE EARTH'S SURFACE.

MATERIALS OF THE GLOBE.—The general arrangement and distribution, both of the materials of the globe and of animated creation, having now been briefly noticed, our next subject of inquiry, before examining more particularly into the internal structure of the earth, may very appropriately be, what are the materials of which it is composed? What are the substances with which it is necessary for us to become acquainted previous to commencing the study of geology? This question leads us at once to two departments of science which are closely connected with geology, and to which it is deeply indebted—chemistry and mineralogy. The geological student does not indeed require to be thoroughly versed in these sciences, a limited knowledge is sufficient for his purpose, but without this knowledge he will make but little progress in the object of his pursuit, and his acquaintance with it will at best be vague and superficial.

The following outline of those essential facts and principles which are most intimately blended with the study of geology will, therefore, materially assist the student, and at least tend to remove some of the most prominent difficulties which most persons have to encounter in obtaining an acquaintance with this science.

The question, what are the materials of the globe? admits of two kinds of answers, as it may be made either to embrace the simple or elementary substances with which we are made acquainted by the chemist, or the various compound bodies which occupy the attention of the mineralogist. The former may be considered as the original elements of creation, while the latter either form the constituents of rocks and soils, or are found in distinct masses interspersed throughout them. The answer to our present inquiry thus comprehends a knowledge of three principal facts—the nature of simple or elementary bodies, the manner and laws of their combination, and the particular mineral bodies which are thus produced. The two former subjects belong to chemistry, while the latter forms the peculiar province of mineralogy.

With a view, therefore, both of saving reference to other works, and of collecting the entire elements of geological science, as far as possible, in one unbroken chain, the following brief outline of those leading facts of chemistry and mineralogy which are most essentially connected with it has been drawn up, and it is hoped will be of material assistance to many readers who may not have studied the latter subjects.

SIMPLE OR ELEMENTARY BODIES.—By a *simple substance*, we are of course to understand a body which, in the present state of chemical knowledge, does not appear to be compounded of other bodies—a substance from which nothing differing from itself can be obtained. Whether, however, such is the real and ultimate constitution of this class—whether they are indeed the actual elements of creation, or whether they are merely its proximate constituents, must be considered as a doubtful point; perhaps many of them may yet be decomposed by the chemist, and reveal a compound nature, as was done by the *earths* in the case of Sir Humphrey Davy's brilliant experiments, while others may be of so subtle a nature as ever to defy the ingenuity of man.

Fifty-four substances are at present included in the list of simple bodies, of which forty-two are ranked as metallic bodies, seven are non-metallic combustibles, and five, when in an uncombined state, exist only as gases. In addition to these known and tangible principles, nature presents us with at least three or four powerful agents which are too subtle in their modes of action and existence to be ranked with the foregoing, or indeed for their separate identity to be decided upon. These are light, heat, electricity, and magnetism, to which the term imponderable elements has been sometimes applied.

METALLIC BODIES.—The numerous class of metallic bodies exhibits certain marked peculiarities of character, which afford grounds for a convenient subdivision of them into three classes—the perfect metals, brittle metals, and metalloids, the former being malleable and ductile, and, therefore, of extensive use to man in the metallic state, while the second, wanting these important properties, are comparatively little used, and the third can with difficulty be brought into the metallic state by the chemist, and, even when this has been done, they spontaneously absorb oxygen, and lose their metallic properties. The second class has sometimes, therefore, been termed semi-metals; these subdivisions are, however, here given rather as a matter of convenience to the student in the classification of a numerous class of bodies than as of any great importance in a chemical point of view.

In the subjoined list of simple substances the metallic bodies are arranged in the order of their affinity for oxygen, a classification which has the double advantage of combining an important chemical characteristic with an approach to the order in which they are valuable to man in their metallic state.

TABULAR VIEW OF SIMPLE OR ELEMENTARY BODIES.

Malleable Metals.	*Brittle Metals.*	*Metalloids.*
Platinum.	Bismuth.	Potassium.
Gold	Antimony.	Sodium.
Silver.	Manganese.	Lithium.
Palladium.	Cobalt.	Calcium.
Mercury.	Tellurium.	Barium.
Copper.	Arsenic.	Strontium.
Iron.	Chromium.	Magnesium.
Tin.	Molybdenum.	Yttrium.
Lead.	Tungsten.	Glucinum.
Nickel.	Columbium.	Aluminum.
Cadmium.	Osmium.	Thorinum.
Zinc.	Rhodium.	Zirconium.
	Iridium.	Silicium.
	Uranium.	
	Titanium.	
	Cerium.	
	Vandium.	

NON-METALLIC COMBUSTIBLES.

Sulphur.
Phosphorus.
Carbon.
Boron.
Selenium.
Iodine.
Bromine.

GASEOUS BODIES.

Oxygen. Hydrogen. Nitrogen. Chlorine. Fluorine.

IMPONDERABLE ELEMENTS.

(Nature and separate identity imperfectly known.)

Light. Heat. Electricity. Magnetism.

Chemical attraction.—Such being the simple or elementary substances of which the earth is composed, we have next to consider the nature of those laws which regulate their combination with each other, for it need hardly be observed that we very rarely find any of them in a simple state; indeed, had it not been for the discoveries of modern chemistry, we should now have been unacquainted with the greater number.

This leads us to the consideration of the great principle pervading all matter, which is termed chemical affinity, or chemical attraction. Simple bodies then are not passive and inert forms of matter; they are all subject in a greater or less degree to the universal principle of chemical attraction by which they tend to enter into combination with each other according to certain fixed laws, and in certain fixed and unvarying proportions. It thus happens that, from the limited catalogue of elementary bodies just given, we are furnished with the almost endless variety of mineral substances of which the earth is composed.

The metals, the metalloids, and the non-metallic combustibles, although capable of entering into an immense variety of combinations with each other, are a comparatively passive class of bodies; the five gaseous elements—oxygen, hydrogen, nitrogen, chlorine, and fluorine—are, on the other hand, exceedingly active principles, combining very readily with the former class, and presenting in their combinations the most intense forms of chemical attraction, or, as it has been happily termed, "the appetency of matter for matter."

PROXIMATE CONSTITUENTS OF MINERALS.—Of these combinations we need, however, only consider here those few which principally enter into the composition of mineral substances: these are chiefly four—*oxides*, *acids*, *earths*, and *alkalies*. The acids also unite with the other three compounds, forming the very numerous class of bodies which are termed *salts*, and which are distinguished by the termination *ate*, as carbonate, sulphate, &c.

The combination of oxygen with the metals and metalloids forms the class of bodies called *oxides*, of which the rust of iron (formed by its decomposing and combining with the oxygen of water) is perhaps the most familiar example. The combinations of oxygen with certain other bases, as carbon and nitrogen, when in so small a proportion that the compound does not possess any acid properties, are also termed oxides. Many substances combine with oxygen in two, three, or more proportions, in which case the first degree of oxidation is called the protoxide, the second the deutoxide or binoxide, and the last the peroxide.

These different degrees of oxidation afford a good example of the fixed and definite proportions in which, as previously noticed, bodies enter into chemical combination with each other. Thus, lead combines with oxygen in three different proportions:—100 parts of lead $+ 7\frac{1}{2}$ oxygen form the protoxide, $+ 11\frac{1}{4}$ of oxygen (or half as much again), it forms the deutoxide, and $+ 15$ oxygen (or twice as much), it forms the peroxide.

Acids are formed by the combination of oxygen (which is the great acidifying principle) with certain acidifiable bases; in some few cases however, as the muriatic (or hydrochloric) and fluoric acids, hydrogen is the acidifying principle. If the base of the acid be saturated with oxygen, the acid is distinguished by the termination *ic*; if not saturated, by the termination *ous*; thus we have both sulphuric and sulphurous acid. The acids have mostly a sour taste; they change the blue, green, and purple juices of vegetables, red. The acids are very important constituents of minerals;

they enter, as before noticed, into the composition of all the various earthy, metallic, and alkaline salts: the best known are the sulphuric acid, or "oil of vitriol," and the nitric acid, or "aqua fortis."

The *earths* are by far the most abundant class of bodies constituting the globe; they are all oxides, or combinations of the metalloids before noticed with oxygen, for which they have so strong an affinity that they are extremely difficult to decompose or to preserve in the metallic state. Hence, previous to the brilliant discoveries of Sir Humphrey Davy, they were always considered as simple bodies. The most abundant of the earths are *silica*, *alumina*, *lime*, *magnesia*, and *barytes*, more especially the first three, which form the principal constituent of all rocks and soils, and, therefore, compose the great mass of the crust or exterior of the globe. *Silica* is seen in its purest form in quartz, or rock crystal; it is the chief constituent of all sands, sandstones, and of flint, and is estimated to form nearly one-half of the entire mass of the globe. *Alumina* forms the characteristic ingredient of all clays, in which it exists in the proportion of from 30 to 50 per cent., the remainder being chiefly silica. *Lime* forms the basis of all limestones, marbles, and calcareous minerals, of which it forms from 50 to 60 per cent.; it is always found in combination with acids, chiefly the carbonic acid. *Magnesia* is an earth well known from its use in medicine; it is much less abundant than the three preceding, but enters into the composition of certain limestones and the rock called serpentine. *Barytes* is still less abundant, and is only of local occurrence in the veins or fissures which often traverse rocks. The remaining earths, *strontian*, *glucina*, *zirconia*, *yttria*, and *thorina*, are of very rare occurrence, and, therefore, of little importance in a geological point of view.

In a state of purity, the earths are all white powders, the colours they assume in various minerals being occasioned by an admixture of metallic matter; their general specific gravity is about 2½. It is remarkable that, while they constitute the most common mineral substances, and consequently the great mass of the globe, that, either in a state of purity or in some of their rarer combinations, they also constitute (with the exception of the diamond, which is pure carbon) the whole class of gems or precious stones.

The *alkalies* have a hot acrid taste; they change the blue juices of vegetables to green, and the yellow to brown; by combining with the acids, they form the class of alkaline salts. The alkalies which form mineral constituents are *soda*, *potash*, and *lithia*, being, like the earths, combinations of metallic bases with oxygen; the former is by far the most abundant and best known, as it forms the basis of common salt, in which it is combined with muriatic acid, forming muriate of soda.

The numerous class of bodies usually termed *salts* are, as before noticed, combinations of an acid with an earth, alkali, or metallic oxide, thus forming earthy, alkaline, and metallic salts. Of these three classes we have familiar examples in chalk or limestone (carbonate of lime), common salt (muriate of soda), and "green vitriol," which is a sulphate of iron.

MINERALOGICAL CONSTITUTION OF THE EARTH'S SURFACE.

MINERALOGY AS ESSENTIAL TO GEOLOGY.—Having now glanced at those combinations of the simple or elementary materials of the globe which form the immediate constituents of mineral substances, we may next proceed to consider such of those mineral substances themselves, as, from their common occurrence, are of the most essential importance to the geologist, and without some acquaintance with which, he can indeed make little or no progress in the object of his studies.

Although the actual number of mineral substances is very great, and the intricacy of their composition and the nice shades of difference which distinguish them contribute to render mineralogy a difficult and complicated study, the geological student need feel but little alarm at the preliminary knowledge of this subject which is required of him. The number of minerals which enter into the composition of rocks is by no means large, and many even of these may, in the first place, be disregarded, confining attention merely to such as are of most common occurrence, and therefore of the greatest importance.

MINERALS ENTERING INTO THE COMPOSITION OF ROCKS.—Of the minerals which usually enter into the composition of the loose earthy materials of the globe, the principal are the well-known substances *sand*, *clay*, and *lime*, which have already been noticed. Variously intermixed and aggregated together, these materials form by far the largest proportion of all loose soils, and also of the softer species of stone, which are in fact the same substances in a more compact form. Thus, most kinds of sandstone are nothing more than loose sands cemented together; the softer kinds of slates, or those which readily soften and crumble away on exposure to air and moisture, are nothing more than indurated clays; and those kinds of limestone which may be readily cut and worked are almost the same thing as chalk, but in a state of greater induration; while *marl*, which is often very hard when first taken from the ground, is merely an indurated admixture of argillaceous and calcareous matter.

The hard crystalline rocks which often occur in elevated and mountainous countries are certainly less simple in their composition, and not quite so easily recognised, yet the great bulk of them are composed of only four mineral substances, *quartz*, *felspar*, *mica*, and *hornblende*, while there are not above half a dozen other minerals which ever enter into their composition in any very important proportion. These are cheifly *garnet*, *augite*, *talc*, *chlorite*, *schorl*, and *carbonate of lime*.

MINERALS FOUND IN VEINS OR BEDS.—The metallic and other minerals which are occasionally interspersed throughout the mass of rocks, but far more generally collected in certain depositaries occupying limited spaces in their mass, are far more numerous, and present a wide range of study to the professed mineralogist; but, restricting our attention to the most common, and therefore the most important of them, the number which is at first essential to be recognised does not exceed about a dozen. These minerals are the following:—*iron pyrites*, *oxide of iron*, *clay ironstone*, *copper pyrites*, *carbonate of copper*, *oxide of tin*, *galena*, *blende*, and *oxide of manganese*, all of which are metallic substances; of the earthy class we may further enumerate, *carbonate of lime*, *sulphate of lime*, *fluor spar*, and *sulphate of barytes*.

As the above minerals are by no means rare or difficult to obtain, the geological student will do well to procure a good specimen or two of each, and attentively to study not only its external form and appearance, but its relative hardness, specific gravity, and mode of fracture. In this manner an acquaintance with the above important minerals, altogether scarcely more than twenty in number, will readily be obtained, and this acquaintance will easily be extended to many other substances, belonging to the same classes, and distinguished by the same general properties.

Although any written description of mineral substances can convey but a faint and inadequate idea of them, and therefore but ill supplies the place of actual examination, the following brief notice of the minerals before enumerated may in some cases prove useful to the student, and will enable him to recognise more readily a substance with which he was not previously acquainted.

CRYSTALLIZATION.—It will be necessary, however, in the first place to draw attention to a fact which must be well known to most persons—that minerals always appear under two varieties of external form, *crystalline*, and *amorphous*. By the term *crystal* is meant any substance formed by nature into a solid bounded by plane surfaces, forming solid angles with each other, and thus possessing a more or less symmetrical figure. By *amorphous* (as the term implies) is meant a body *not* possessing any regular or symmetrical figure: it is frequently also called *massive* or *compact*. Nearly all minerals are occasionally found crystallized; and, although the primary forms of crystals are very few in number, they are so curiously modified in the process of crystallization, as to be almost infinitely varied. Of this *calcareous spar* affords a very interesting example: it is found crystallized in no less than 500 different varieties of form, yet all derived from a peculiar rhomboidal figure, which is hence regarded as its primary crystal.

DESCRIPTION OF MINERALS COMPOSING ROCKS.—The following description will convey the most important characteristics of the mineral substances before enumerated, as the chief constituents of hard and crystalline rocks:—

Quartz is almost pure silica; its general appearance much resembles glass, though not generally quite so transparent: the clearest and finest specimens are often called *rock crystal*. It is very hard, and readily scratches glass, and, indeed, most other minerals. When crystallized, its form is generally that of a six-sided prism, terminated by a six-sided pyramid, or often a six-sided pyramid only.

Felspar is composed of silica, alumina, lime, and potash: it is opaque, of a whitish or reddish colour, and less hard than quartz, but still capable of scratching glass. It occurs crystallized in a rhomboidal form, and also very frequently massive or compact.

Mica is chiefly composed of silica, alumina, potash, and oxide of iron: it is composed of thin parallel plates having a bright metallic lustre; its colour is usually light brown or sometimes black, and the plates are often very transparent like glass. This mineral is soft and yields readily to the knife.

Hornblende is composed of silica, alumina, lime, magnesia and oxide of iron: it is a dark green mineral, sometimes nearly black. It is generally crystallized in a prismatic form, or rather a confused aggregation of crystals; it does not break readily, is very tough, and yields to the knife.

Garnet is composed of silica, alumina, lime, and oxide of iron: it is a mineral of a deep red colour and well known from its being much used for ornamental purposes. There are two species of garnet, the common and the precious; the principal difference in their composition is, that the latter contains a much larger proportion of iron than the former. Garnet is very hard, sufficiently so to scratch quartz, and is so abundant in some rocks as almost to form one of their constituents.

Augite is very similar to hornblende in its composition: it generally occurs in small but very brilliant crystals, of a brownish or blackish colour. It is chiefly found in the neighbourhood of volcanoes.

Talc is composed of silica, magnesia, and potash: it nearly resembles mica, but does not possess the elasticity of that mineral; it is very soft and unctuous to the touch.

Chlorite is composed of silica, alumina, oxide of iron, and magnesia: it is a mineral of a green colour, soft to the touch, and frequently occurring in small grains or crystalline plates interspersed through other mineral masses. It is abundant in Cornwall, especially in the tin mines, and is termed by the miners "peach." The mineral called *green earth*, which occurs plentifully in certain rocks, is very similar to chlorite in its composition, and may indeed be considered as merely an earthy variety of it.

Schorl is composed of silica, alumina, and oxide of iron, with a little magnesia, and potash; its colour is generally black, sometimes green; it occurs in long prisms closely aggregated together, and sometimes striated by longitudinal channels. It is often called "cockle" by the miners of Cornwall, where it enters into the composition of certain granitic rocks.

Carbonate of Lime is composed of lime and carbonic acid, in nearly equal proportions, and is the chief constituent of all limestones and calcareous rocks, both earthy and crystalline, the two extremes of the series being *chalk* on the one hand, and the white crystalline *marble* used for ornamental purposes on the other. Calcareous rocks are so abundant that they have been estimated to form one-eighth part of the crust of the globe. The colour of all pure limestones is white, but they receive an infinite variety of tints, as may be seen in ornamental marbles, from the admixture of iron and other ingredients. Rocks of this class differ greatly in hardness, but all yield to the knife. The presence of lime in rocks or minerals may readily be ascertained by the action of acids, which occasion an immediate effervescence, from the disengagement of the carbonic acid gas.

DESCRIPTION OF MINERALS FOUND IN VEINS—METALLIC MINERALS.—The earthy minerals forming the chief constituents of rocks will readily be recognised from the foregoing description, and we may now proceed to those minerals, chiefly metallic, which are collected in great local abundance in certain masses or depositaries imbedded in rocks, the principal of which are *beds* or layers, and *veins*, or the contents of long narrow fissures, which sometimes traverse them.

There are two characters which in most cases readily serve to distinguish metallic minerals from all others: these are a brilliant metallic lustre, and great specific gravity. The latter character is at once ascertained by taking the mineral in the hand; the specific gravity of the metallic minerals being in most cases double, and often from twice to three times as great as that of the earthy class.

Of all the metallic minerals, *iron* is by far the most abundant and the most generally distributed; there is indeed scarcely a rock or soil in which it does not occur. Its ores are numerous, but the three most important are, iron pyrites, oxide of iron, and clay ironstone.

Iron pyrites is composed of iron and sulphur, in nearly equal proportion: it is brilliant, of a pale brass yellow, and generally crystallized, often in cubes. It is hard enough to scratch glass, and to give fire with steel.

Oxide of iron is iron combined with oxygen, and differs much in appearance according to the degree of oxidation, and intermixture with other substances; some varieties being red and earthy, others of a dark brown colour, and others of a steel gray with a bright metallic lustre; the latter is termed specular iron. Iron in the state of the protoxide is highly magnetic, and forms the "native loadstone," but in the state of the peroxide loses its magnetic properties.

Clay ironstone is a very impure carbonate of iron: it is generally of a light brown colour, and occurs in large nodular masses in our coal-mines.

Copper pyrites, or "yellow copper ore," is a sulphuret of copper and iron: it is generally of a bright yellow colour, not crystallized, and yields to the knife. Its comparative softness and deeper yellow tint will in most cases distinguish it from iron pyrites, to which it has some resemblance.

Carbonate of copper forms two varieties, the *blue* and *green*: it occurs both crystallized and massive.

Oxide of tin, or common tin ore, generally occurs massive, but is often found in fine brilliant crystals of various forms: the colour is black or approaching to it.

Galena, or sulphuret of lead, is a very heavy mineral of a bluish colour, and bright metallic lustre. It is often crystallized, but more generally massive with a foliated fracture.

Blende, or sulphuret of zinc, is a dark brown mineral often occurring in fine brilliant crystallizations, though more generally massive; it is somewhat like tin ore, but less heavy.

Manganese is always found in the state of an oxide: it generally appears as an earthy substance of a blackish colour, which yields readily to the knife, and is sometimes even soft and friable.

Earthy minerals.—*Carbonate of lime* (as a local mineral) is usually crystallized in a great variety of forms, most often in that of rhomboid: it is sometimes clear and transparent, and possesses the singular property of double refraction. It is more generally whitish or yellowish, and only translucent; it yields to the knife and effervesces readily with acids.

Sulphate of lime, or gypsum, is generally aggregated together in crystalline fibres; the colour is white or yellowish, and it readily yields to the knife.

Fluor spar is generally of a purple colour: it occurs both massive and crystallized in cubes.

Sulphate of barytes, when pure, is perfectly white, but is commonly tinged of a brownish colour by an admixture of iron. It occurs massive, forming what is termed by the miners in the north of England "cawk," and also very frequently in thin-edged crystals, which are closely aggregated together. It is remarkable for its weight, being indeed the heaviest of the earthy minerals, and is very brittle.

Relative hardness of minerals.—Although the acquaintance with mineralogy, which is absolutely requisite in the geologist, is by no means extensive, a want of this knowledge is perhaps the greatest obstacle which is generally encountered by persons entering upon the science. The preceding pages will have done much to remove this difficulty: it is possible, however, by a brief reference to a very obvious property of minerals, to do still more, and to furnish an easy guide to the recognition of a considerable number of mineral substances, to those who have but a slight acquaintance with their other chemical or external characters. It will have been observed that in the foregoing description frequent reference is made to the *relative hardness* of the substance under consideration, and, by the mere application of this principle, we may obtain a very simple classification embracing a large number of important minerals. Thus, there are certain minerals hard enough to scratch *glass*, while others, being much softer, are sectile, and yield to the *knife*—evidently important and simple modes of recognition. The principle may, however, be extended much further:—taking *quartz* as having a maximum hardness opposed to glass, there are several other minerals by which it may itself be scratched, as the *garnet* and *topaz*,—in fact all the softer class of gems. These may again be scratched by the *diamond*, *sapphire*, and some few other precious stones, in which are presented the maximum of hardness, in fact the hardest bodies formed by nature. Thus, then, taking glass, a substance always attainable, as our standard, three characteristic degrees of hardness are at once perceived.

The same principle is, however, no less applicable to the softer class of minerals than to the harder. Of those substances which are softer than glass, several, as *fluor spar* and *carbonate of lime*, may be cut with a knife, others softer still yield to the nail, as *gypsum*, *mica*, *talc*, and *steatite*, while in *naphtha*, *petroleum*, and *native mercury*, we are presented with mineral bodies in a state of natural fluidity.

The following tabular view of the relative hardness of minerals was drawn up by the author for his own use while studying mineralogy, and may be made very serviceable by the student who will apply this simple principle to those minerals which he may happen to possess, or which chance may throw in his way. As regards the harder class of minerals, the experiment should always be made with the *points* or solid angles of crystals, these being much harder than any edges or surfaces produced by fracture.

RELATIVE HARDNESS OF MINERALS.

Class.	*Characteristic.*	*Nature of the Substance.*	*Names of the Minerals.*
1	Excessive hardness	Precious stones .	Diamond, sapphire, oriental ruby, chrysoberyl, spinel ruby, emery.
2	Scratch quartz . .	Softer gems . .	Garnet, hyacinth, topaz, beryl, emerald.
3	Scratch glass . .	Chiefly siliceous minerals.	Quartz and oxide of tin—iron pyrites and arsenical pyrites, chrysolite, felspar, flint, hornstone, epidote.
4	Yield to the knife .	Mostly acidiferous minerals.	Fluor spar, carbonate and sulphate of barytes, arrogonite, carbonate of lime and calcareous spar, copper pyrites, serpentine, slate.
5	Yield to the nail .	Acidiferous and alkaline minerals—metallic chlorides, &c.	Gypsum, mica, talc, steatite, chalk, marl, clay, bitumen, chloride of silver, chloride of mercury.
6	Naturally fluid. .	Mineral oils and native mercury.	Naphtha, petroleum, native mercury.

The foregoing tabular view will exhibit in a tolerably perfect manner the relative hardness of many important minerals, and thus furnish a useful guide to the student, who may perhaps repeat the experiments and enlarge the list with advantage to himself. As regards other characteristic properties, it may be observed, that the important mineral *hornblende* is remarkable for its toughness, a property which it imparts to all rocks in which it forms a large ingredient. *Sulphate of barytes* and *galena*, on the other hand, are remarkably brittle, and immediately break into small fragments under the hammer, while nearly all *acidiferous* minerals are very soft, and readily yield to the knife.

PART II.

ELEMENTARY FACTS AND PRINCIPLES OF GEOLOGY.

Introductory Remarks—Limits of Geological Investigation—Familiar Geological Facts—Generalization. FUNDAMENTAL FACTS OF GEOLOGY—THEORETICAL DEDUCTIONS: Aqueous Agency—Igneous Agency—Vital Agency—Generalization—Identity of Ancient Geological Causes with the present Operations of Nature—Dudley Limestone—Induration of Rocks—Sketch of Geological Theory—Agreement of Geological Facts with Scripture. CHANGES OF THE EARTH'S SURFACE NOW IN OPERATION: Changes produced by Aqueous Action—Alluvial Deltas—Undermining of Cliffs—Drifted Sands—Raised Beaches—Submarine Forests—Littoral Deposits—Phenomena of Volcanoes—Theories of Volcanic Action—Phenomena of Eruptions—Changes of the Earth's Surface produced by Volcanic Action—Extinct Volcanoes—Recent and Submarine Volcanoes—Earthquakes—Their permanent Effects—Theoretical Views—Coral Reefs—Practical Value of the foregoing Facts—Limitation of existing Changes—Fluctuations in the Level of the Land. CLASSIFICATION OF ROCKS: Tabular view of Stratified and Unstratified Rocks.

INTRODUCTORY REMARKS.—The preliminary views which have now been given will have conveyed a clear and accurate idea of all the most general relations of our planet, a knowledge of which ought always to precede every other branch of geological inquiry. The preceding pages have, therefore, conducted the reader step by step to the more immediate objects of geological science—the internal structure of the globe, and the composition and arrangement of the great mineral masses of which its crust is composed. To obtain a thorough and correct knowledge of these important points, both locally and generally, is the great object of the geologist, and more especially of the practical geologist; and when we consider the expense and labour of penetrating into the earth, the frequent recourse which must be had to such excavations, and the vast utility of the substances which we extract from thence, it must at once be seen that this knowledge is of the highest value, and ought to be possessed to a certain extent, not only by the miner and engineer, but also by the architect, the landed proprietor, and many others.

LIMITS OF GEOLOGICAL INVESTIGATION.—The objects of geological investigation, although co-extensive with the whole mass of the globe, being considerably limited as regards the power of direct examination, it will be necessary in the first place briefly to notice the extent and nature of this limitation.

As the vast central mass of the globe must for ever remain entirely hidden from our view, it is of importance to define clearly the extent of that portion which either directly or indirectly falls within the observation of the geologist. Taking then the surface of the ocean, as indicating the general level of the earth, we are acquainted by the elevations of hills and mountains with the portion which rises *above* that level, while our only knowledge of what lies *below* is derived from mines and other excavations.

It is well known that the highest mountains rise but five miles above the level of the sea, while the deepest mines penetrate little more than a quarter of a mile below it; all our direct knowledge therefore is confined within these narrow limits, amounting to little more than one eight-hundredth part of the earth's semi-diameter. There are indeed but few parts of the world which afford so large a scope to direct observation, but by inference we are generally enabled to penetrate much deeper than by actual examination, and it may probably be stated that we are in general acquainted with the mass of the globe for a perpendicular distance, varying from four or five to eight or ten miles.

It can be hardly necessary to point out how greatly our knowledge of the earth's *surface* is circumscribed by the vast extent of the ocean, which is estimated to cover about two-thirds of the superficial area of the globe. The depth of the ocean bears, however, but a small proportion to its magnitude; its bed has been shown to be marked by similar inequalities to those which form hills, mountains, and valleys on the land, and there is no reason to suppose that these inequalities are of greater depth or extent than those seen upon our continents. A large portion of the sea is known to be comparatively shallow, and those depressions constituting its deepest gulfs do not probably often exceed four or five miles in depth.

FAMILIAR GEOLOGICAL FACTS.—The science of geology embraces, and is indeed founded upon, so many natural phenomena, which are obvious and familiar to all, that it will not, perhaps, be difficult to convey a brief outline of many of its first principles, by reference merely to facts which are obvious and well known, or which will at least be generally recognised when they have been pointed out, nor will it be necessary to embarrass such a sketch with many scientific terms, or with theories not readily intelligible to the ordinary reader.

It is then upon these principles that the present outline of the subject will be attempted; and, after stating one or two leading facts, we may consider ourselves as following the progress of an intelligent traveller, well acquainted with the preceding elementary data, who, with a view of ascertaining certain general principles relative to the earth's configuration, observes with care the physical aspect and internal structure of the country over which he passes.

We are all aware that both the earth's surface and its interior, so far as is exposed to our view, are composed of various *earthy substances*, and of others of a *stony* or *rocky* nature, and that these substances vary in different places, often at no great distance from each other.

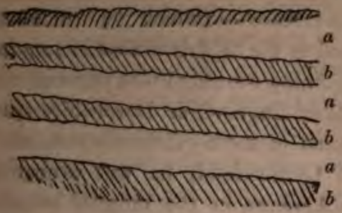
Of the former class, or the loose earthy materials of the globe, the vicinity of London, and the south-eastern parts of England generally, are examples—here we find, frequently within a short space, *gravel*, *clay*, *chalk*, *sand*, and various kinds of earthy *limestone*. Of the latter class, or the hard rocky materials (which are generally however concealed by a superficial covering of loose soil), the western and northern parts of England, as well as large portions of Wales, Scotland, and Ireland, afford instances; fine compact *limestones* or *marbles*, together with different varieties of *slate* and *granite*, occurring abundantly in all these places.

Few persons who have travelled over any considerable portion of Great Britain can fail to have observed, that, where the former class of substances, or loose earthy matter, predominates, the country is generally low and flat, destitute of mineral productions, but fertile and well cultivated; while the latter class, or rocks, generally forms elevated, and often mountainous and barren districts, in which, however, are situated most of our great mineral and metalliferous deposits.

There are perhaps few facts more obvious and better known than that the earthy and stony masses before noticed very generally rest upon each other in *beds* or *layers*, which are sometimes in a horizontal position, and sometimes more or less inclined to the horizon.

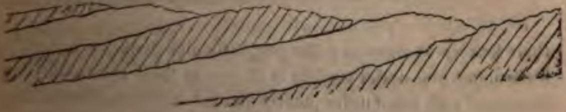
This may readily be seen wherever the ground has been laid open by a chalk-pit, a quarry, or any other excavation, or where a natural section is presented to our view, as by naked masses of rock, or by cliffs on the sea-shore; and an intelligent observer, after viewing a section of this kind, could hardly fail to recognise a certain degree of order and regularity in the arrangement of these masses. He would probably find them to consist of regular alternations or repetitions of similar strata, as shown in the annexed diagram, where *a a a* may be supposed to represent beds of sandstone, and *b b b* beds of limestone, lying between and beneath them.

Fig. 2.



Should a different line of coast, or an excavation in another part of the country, receive a similar examination, the same facts would probably be observed, but the nature of the strata would perhaps be entirely different from the former. The inclined position of these masses (for they generally dip towards some point of the horizon) would at once show that such changes are occasioned by those beds which in some places appear at the surface, being in others buried at an immense depth below it, and *vice versâ*, the exterior of the globe being thus in fact composed of various beds or strata, emerging from under one another, in the manner shown below.*

Fig.3.



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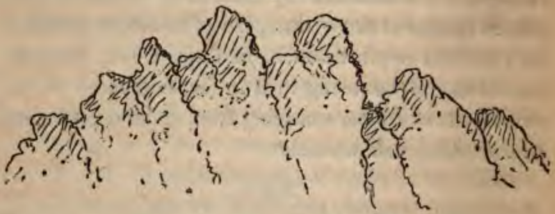
[*] Connected with the subject of *stratification*, there are a few geological terms which will require explanation. The point where the beds or strata rise to the surface is called their *basset* or *outcrop*; the angle at which they incline below the horizon is their *dip*; the line formed by their outcrop at the surface is

Should the observer we are supposing continue to pursue his researches (which we will assume to have commenced in the neighbourhood of London or in one of the adjoining counties) into some of the more remote parts of England, as Devonshire and Cornwall, or into some of the northern districts, as Westmoreland and Cumberland, he will probably notice a striking difference in the internal structure of the country, as, instead of slightly-inclined beds of clay, or chalk, &c., he will find the interior to consist of *granite*, *serpentine*, *greenstone*, or *basalt*, rocks showing no appearance whatever of regularity or stratification, but appearing to shoot up from below, in rude and abrupt columnar masses—thus:

Fig. 4.



their *bearing* or *direction;* the perpendicular distance between their upper and under surface is of course their *thickness.* A *stratum* of rock is not unfrequently divided into subordinate *beds* or *layers* by joints parallel to its bounding surfaces, and these are not unfrequently crossed again by vertical *joints,* dividing the whole mass into cubical or rhomboidal masses. Some rocks, as slates, are still further subdivided, by innumerable parallel joints, or *lines of cleavage,* into exceedingly thin *laminæ,* which form the last term of the geological series.

There are, perhaps, few circumstances more generally known, or which would sooner engage the attention of the observer, than the occurrence of what are termed "*petrifactions*," or the mineralized remains of a great variety of animal and vegetable productions, which so often occur in rocks. It would not require much examination to prove, that, although in some strata, as the clay and chalk around London, they are very abundant, in other rocks, as granite and many kinds of slate, they are never known to occur.

Should the position of these interesting relics, with relation to the rocks in which they are contained, receive attention, it will immediately strike the observer that it is only in those substances which are disposed in beds or layers that they occur, while it is in those which form abrupt and columnar masses that they are entirely wanting.

There is another fact connected with the subject which could hardly escape notice. In some parts of the country certain fossils are so abundant as to be well known among the peasantry, and to have received familiar local names supposed to be descriptive of their form or origin. Thus the *echini*, so common in chalk districts, are in some places called "shepherds' crowns;" the *ammonites*, which are so abundant in many parts of England, are called "snake-stones;" the *belemnites*, so plentiful in the same localities, are called "thunderbolts;" while the *entrochites* of Derbyshire and the northern counties are locally termed "screw-stones," and, in some parts of Yorkshire, "pipe-stoppers." If this local abundance of particular fossils, so striking as to cause familiar appellations among the labouring population, should receive attention, the observer would find that, where any species of "petrifaction" abounded, some particular kind of rock would also prevail, in which it was usually found imbedded. Thus, then, a close connexion would be established between *rocks* and *fossils*, the one being evidently to a certain extent characteristic of the other.

Should any attempt be made to classify the various rocks which have been the subject of the preceding observations, there is one very important character, which will at once serve to determine them into two great divisions—that of *stratification*. Thus, all those masses found in beds or layers may very appropriately be termed *stratified rocks*, while those occurring in abrupt and shapeless masses may in the same manner receive the name of *unstratified rocks*.

Thus then we establish one of the most important classifications in geology; and, as before stated, we may also observe, as a general principle, that the former class is *fossilliferous*, while the latter is *non-fossilliferous*, evidently another distinction of considerable importance.

If the aspect and composition of these two great classes of rocks should receive further attention, another very marked difference will be found to prevail. The stratified rocks, however varied in appearance, will be found to consist almost entirely of those well-known substances, *sand*, *clay*, and *lime*, variously aggregated together, in the forms of *sands* and *sandstones*, and still more compact *siliceous rocks*—as *clay*, *slate-clay* (or *shale*), and compact *slate*—as *chalk*, *limestone*, and compact crystalline *marble*. The unstratified rocks, on the other hand, will be found, under all their various forms and aspects, to be principally composed of crystalline aggregations of the four mineral substances previously described, termed, *quartz*, *felspar*, *mica*, and *hornblende*. The three former of these substances we are best acquainted with in the shape of *granite*, which consists of a distinct aggregation of each in a crystalline form*. The latter is perhaps best known in the rocks termed *greenstone* and *basalt*, to the former of which it imparts its characteristic hue, a deep green colour.

As regards the relative position of the stratified and unstratified rocks, should this happen to be exposed to view, either by excavations or by cliffs along the shore, the observer would probably find that the former have the highest relative situation, and rest upon the latter, which would be seen rising from beneath them, as shown in the accompanying sketch. Fig. 5.

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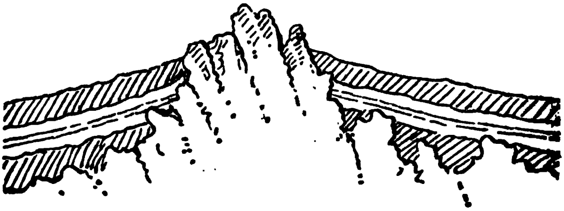
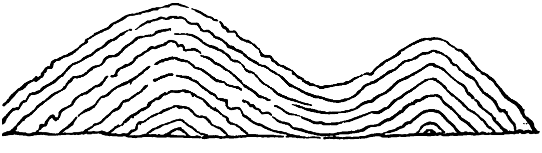
* The prevailing substance in granite is generally the *felspar*—it is of a whitish or sometimes of a reddish colour, quite opaque, and occasionally crystallized in a rhomboidal form. The *quartz* is rather less abundant; it is somewhat transparent, and of a glassy appearance. The *mica* is dispersed throughout in small glistening plates; the colour is dark, and the appearance metallic.

Fig. 5.



On viewing a section of this kind, in which the junction of the stratified and unstratified rocks was exposed to view, the observer would probably find that the former were of a more crystalline structure, and were thrown into a more inclined position than he had previously seen, or they might perhaps be bent and contorted, circumstances indicating that these irregularities of position were connected with the presence of unstratified rocks, even in cases where the cause might not be visible. The annexed sketch, Fig. 6, represents contortions of Greywacke slate occurring in Cardiganshire; and such irregularities of the strata are common in most mountainous countries, unstratified rocks being always most abundant in abrupt and elevated districts.

Fig. 6.



Generalization.—We have now, then, traced some of the leading facts of geological science, in the order in which they may be supposed to present themselves to an intelligent observer, whose attention was directed towards the internal structure of the earth; and in so doing have indeed only followed the footsteps of some of the earlier cultivators of geology, although placed by their discoveries in a position to arrive much more expeditiously and certainly at the same results.

If we now proceed to generalize these facts, obvious in themselves, and accessible to every one, many of which indeed the reader may previously have observed, although not conscious of their importance and value, we shall arrive at the following interesting conclusions, which are in strict accordance with the observations of geologists in every quarter of the globe; and may therefore be considered as forming the foundation of the science, so far as it consists of facts;—of theory, further than what appears indispensable to a proper understanding of the subject, but little notice can be taken in the present outline of geology.

FUNDAMENTAL FACTS OF GEOLOGY.

1. The exterior solid mass of the globe is composed of various loose or *earthy*, and of various compact or *rocky*, materials.

2. The former, or earthy substances, generally constitute level and fertile tracts of country, destitute of mineral productions.

3. The latter, or rocky substances, generally form

mountainous and barren districts, which often contain the ores of various metals, as iron, lead, copper, tin, &c.

4. These materials, constituting the exterior of the globe, very generally occur in *beds* or *layers*, resting one upon another.

5. In some places, however, and more especially in mountainous countries, there are vast and abrupt masses of *granite* and other rocks, having *no* appearance of stratification.

6. Those materials occurring in beds or layers are sometimes in a horizontal position, but often more or less inclined to the horizon, and sometimes even bent and contorted.

7. The inclined position of certain beds frequently occasions the diversity of soil before mentioned, by bringing different masses in succession to the surface, which in other places must lie at a great depth below it.

8. The space thus occupied at the surface must generally be much greater than the *absolute thickness* of the bed itself.

9. A certain degree of *order* exists in the distribution of these masses, which are by no means promiscuously thrown together.

10. Some of them contain numerous fossil remains imbedded, as *shells*, *corals*, *fishes*, *bones of land animals*, *plants*, *trees*, &c., thus indicating great changes to have taken place in the condition of the globe, more especially as regards the distribution of land and water.

11. Others, on the contrary, present no traces of organized bodies.

12. These fossil remains are entirely confined to those earthy and rocky masses, which are disposed in beds or layers, while they are *never* found in those which appear in rude, irregular, and columnar piles.

13. Certain species of fossils are most abundantly found in certain kinds of rock, and may therefore be considered as characteristic of them.

14. All the various solid masses constituting the exterior of the globe, admit, on the preceding grounds, of a convenient separation into two great divisions, which may be termed *stratified* and *unstratified* rocks, to which the further distinction of *fossilliferous* and *non-fossilliferous* may, in general terms, be respectively applied.

15. As regards their actual composition, nearly the whole mass of stratified rocks, or those found in beds or layers, may be considered as *sand*, *clay*, and *lime*, variously aggregated together, in forms more or less compact.

16. Viewed in the same manner, the whole mass of the unstratified rocks may be considered as aggregations of a few mineral substances, chiefly *quartz*, *felspar*, *mica*, and *hornblende*—these aggregations being always of a crystalline texture, and possessing in most cases considerable hardness and compactness.

17. In reference to the relative position of these two great classes of rocks, with regard to each other, the stratified rocks, in most cases, occur *above*, and

the unstratified rocks *below;* the one, as it were, forming the foundation, while the other constitutes the superstructure of the globe.

18. The inclined position of the stratified rocks is most remarkable in the neighbourhood of those which are unstratified; and in these situations they sometimes exhibit great dislocation and contortion, as well as a more crystalline structure than elsewhere.

THEORETICAL DEDUCTIONS.

After thus recognising many of the fundamental facts of geology, it would be difficult for the observer to avoid speculating on the various phenomena which he had examined, on the varying conditions of the earth's surface which they indicate, and on the causes from which they might have originated. The first impression on the mind would probably be, that the stratified exterior of the globe, far from being contemporaneous, had been gradually *built up*, as it were, into its present form, and that the earth once existed in a different state, and under different circumstances, from what it now does; a fact testified by the existence of shells and corals in a fossil state, far removed from the sea, and often at elevations of many thousand feet above its present level, by the occurrence of magnificent plants and trees of unknown species and tropical growth imbedded in our quarries and coal-mines, and by innumerable bones and fragments of enormous and extinct animals, buried in various strata deep below the surface.

This conclusion would be perfectly just and reasonable; and decisive indications are not wanting of the nature of the agents employed, in the mighty operation of successively remodelling the face of the globe, and finally bringing it into its present condition.

Aqueous agency.—When we view the vast accumulation of the stratified rocks, consisting of almost innumerable layers resting one upon another, often made up in great measure of *water-worn fragments or pebbles*, evidently derived from other strata still lower in the series, or more generally of finely-comminuted sedimentary matter; when we find these layers frequently containing in profusion *corals*, *shells*, and even *fishes* in a fossil state, the conclusion is obvious and inevitable, that they were formed by the agency of *water*, and that the space they now occupy must, at some remote period, have been the bed of the ocean, which, owing to some mighty revolution, has since undergone considerable change both of situation and of relative level. This conclusion indeed is so evident, that we find it distinctly recognised by one of the most fanciful writers of antiquity, Ovid, in the well-known lines—

> " —— Vidi factas ex æquore terras;
> Et procul a pelago, conchæ jacuêre marinæ."

Igneous agency.—The origin of the unstratified class of rocks is certainly of a less obvious nature, yet the deductions respecting it are equally satisfactory. From their *not* being disposed in beds or layers, and from their containing *no* fossil remains, we derive the strongest negative proof that their origin was not sedimentary, and that it had no connexion with the agency of water.

On the other hand, the modes in which they occur in all cases strongly countenance the idea of injection from below; often, indeed, this mode of formation is at once apparent, and their occasional striking resemblance to the products of existing volcanoes shows that the agency by which they were produced was that of *subterranean heat*, and therefore closely resembling, if not identical with, *volcanic action*.

As these views, however, do not admit of such ready confirmation as those adduced with respect to the origin of the stratified rocks, one or two decisive facts in support of them may not be misplaced.

When dykes, or masses of *basalt*, come in contact with beds of coal (a circumstance which often happens in the north of England), the coal in its vicinity is generally found to be converted into *coke* or *cinder*, clearly proving that, when the basalt assumed its present position, it must have been in an intensely heated state; and as it now occurs, *completely filling up irregular rents or chasms* in the coal-strata, there can be no doubt that when ejected from below it was in a state of *actual fusion*, and that the strata were fractured by the force which propelled it upwards. Were further proof needed that such is the origin of basalt, it would be furnished by the fact that this rock often exactly resembles the more compact *lavas* known to have issued from volcanic craters, this resemblance extending not merely to external texture and appearance, but to actual chemical composition.

We have thus clearly established the igneous origin of one member of the unstratified class of rocks; and it is sufficient to observe that, by equally satisfactory, though perhaps less self-evident reasoning, the same origin may be ascribed to all the rest. In this manner it will be seen that, by a strict process of inductive reasoning, we are enabled to arrive at conclusions, no less interesting than important, with regard to the nature of those powerful agents employed in modifying the original materials of the globe, and in giving them their present form and position.

VITAL AGENCY.—On examining still more closely into the nature of the mineral masses constituting the globe, we should occasionally meet with strata almost entirely composed of shells and corals, cemented together into a solid rock; we must therefore add a third occasional agent—vital or organic action.

GENERALIZATION.—It will hence be seen that on simple and intelligible grounds the formation of the rocks and strata composing the crust of the globe, however various in their nature and appearance, may always be referred to two principal causes—*oceanic* agency on the one hand, and *volcanic* agency on the other—that we have a general mass of stratified rocks spread over a large portion of the globe, which admit of a close comparison with those sedimentary deposits which are now being formed by the ocean in situations where loose materials are swept into it by rivers, or drifted by currents from the wearing down of cliffs, while beneath and protruding through this covering there are vast unstratified masses nearly analogous to the liquid mineral matter which is now poured forth by volcanoes. Further, in addition to these general agents, shells and corals have in some situations contributed a large proportion of calcareous matter towards the materials of the globe. These universal and striking facts form the foundation of all geological theory, and for this reason they are thus prominently brought under the reader's notice.

IDENTITY OF ANCIENT GEOLOGICAL CAUSES WITH THE PRESENT OPERATIONS OF NATURE.—Having firmly established these great principles, we may however proceed much further,—we may examine into the nature and conditions of those sedimentary deposits which are now in process of formation, whether by the sea, by lakes, by rivers, or by mineral and thermal springs, and we may then proceed to investigate the points of similarity between these modern depositions which are actually taking place before our eyes, and those more ancient and extensive ones which were formed when the "Spirit of God moved upon the face of the waters," and brought the materials of the globe, before "without form and void," into their present orderly and beautiful arrangement. The results of this investigation, with the collateral aid of zoology and botany, form indeed the great mass of geological science; and, while deeply interesting as unfolding the early history of the globe, they are distinguished by a certainty and precision which stamps them with a double value. Not only is a close analogy established between the present operations of Nature and her ancient workings, but in many cases a complete *identity*; in fact, the whole series can be shown to have formed one unbroken chain, every link of which may be distinctly recognised.

Thus, then, the origin of every stratified rock may be distinctly traced; some, as the *chalk*, being marine; others, as the *Wealden*, formed in estuaries; while, as in the Isle of Wight strata, we are occasionally presented with alternating layers of marine and freshwater formation.

This absolute identity of modern agencies with the most ancient operations of nature, and more especially with those vast processes by which the earth received its present form and structure, is a proposition of so much geological importance, and at the same time so little in unison with the received ideas of persons not conversant with the subject, that it may be well to afford a few simple demonstrations of its correctness.

Among modern aqueous formations, beds of soft mud, of loose sand, and of sand and pebbles intermixed, are the most common, and to the casual observer there is no great resemblance, still more anything like an actual identity between these substances and the hard compact layers of rock which form the earth's surface. Although the latter have been acted upon and modified in their texture and appearance by various powerful indurating and consolidating agents, the geologist can, however, readily prove that all clays and slates were originally soft mud, that the hardest sandstone and quartz rock was originally loose sand, and that the conglomerates, or "pudding-stone" rocks, so common in the north England and elsewhere, and often so hard as to defy the miner's pick, were originally nothing more than loose shingly beds. A few only of these proofs will be here sufficient, and the examination of a small number of characteristic geological specimens will at once force conviction on the mind.

When we find any substance containing an exact impression of the form of a body, there can be little doubt that the substance thus impressed was originally soft and yielding, whatever its present state may be; but if the body from which the impression is taken is itself soft and fragile, and the impression is received with the most perfect accuracy and minuteness, the original softness of the substance bearing the impression amounts to an absolute certainty. Now this is precisely what happens with the most indurated clays, shales and slates, in which the most beautiful impressions of shells and plants are very frequently preserved, thus proving their original condition to have been that of very fine soft mud. Sandstone, however indurated, may in the same manner be traced back to its former state of loose sand, for it has often been observed in quarries that the upper face of the layers of sandstone are perfectly impressed with the *ripple of the waves*, in the same manner as we now see the soft sands on the sea-beach; further than this, sandstone has been often found to contain those singular impressions called *ornithicnites*, which are well ascertained to be footsteps of large extinct species of birds. Conglomerate rocks rarely contain organic impressions, the greater violence of the water in which they were formed hardly admitting of such an occurrence; but, both from the mode in which the materials are arranged and the obvious nature of the cementing principle, they may always be referred to the original condition of loose shingly sand and pebbles.

DUDLEY LIMESTONE.—The examination of a few good geological specimens will at once render these truths apparent, and the student would do well to obtain a characteristic piece of the "Dudley limestone," which should form one of the earliest specimens in his collection. The instructive nature of this rock will best be understood from a brief description of a specimen now lying before the author, and it will be seen how admirably it exemplifies the principles which have just been stated. A thin slab of rock about a foot square, and of a calcareous nature, is covered on its upper surface with fossil shells, corals, and the singular crustaceous animals called *trilobites*, all in a state of the most exquisite preservation, and lying imbedded in the stone precisely in the same manner that recent shells and branches of coral are strewed over the bed of the present sea. An examination of the nature of the stone, and the distribution of the fossils on its surface, will at once render it evident that in its original state it formed a thin layer of calcareous mud spread over the bottom of the ancient ocean, and that the inhabitants of that ocean have been fixed and mineralized upon it, precisely in the position in which they happened to lie when the next succeeding layer was deposited, and in which they became enveloped. The Dudley limestone is a rock which lies considerably below the coal-formation, and indeed close upon the verge of those strata in which organic life first makes its appearance. What spectacle then can be more interesting than thus to see embalmed in the solid rock some of the earliest inhabitants of our planet, precisely in the mode in which they naturally lay on the bed of that ancient ocean, which existed before perhaps a tenth part of the surface of the British islands was raised from the waves, and before those plants of luxuriant growth existed, which in the long course of ages were converted into our greatest national treasure—our beds of coal!

INDURATION OF ROCKS.—The mode in which the soft sedimentary deposits of the ancient ocean were converted into the hard and compact rocks which now form the surface of the globe, is of course an interesting subject of inquiry, and will be treated on in the latter part of this volume. It is sufficient here to observe, that this change is chiefly owing to three general causes—the influence of subterranean heat, consolidation by pressure, and the chemical action of cementing matter, which even in recent deposits often binds loose materials together into a hard solid mass.*

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* Instances of the induration, or rather consolidation, of loose materials, from the vast pressure of the superincumbent strata, are often observed in mines, in cases where rubbish has been thrown into old excavations, so as to fill them up. For the following very remarkable and well-authenticated example,

SKETCH OF GEOLOGICAL THEORY.—It would far exceed our prescribed limits to enter into the subject of geological theory further than appears requisite in order to obtain a proper and comprehensive view of the nature and causes of geological phenomena, without which a bare detail of facts could possess little interest, and indeed would hardly be intelligible. The following sketch will briefly explain the nature of those great revolutions which the earth appears to have undergone, and from which its present state has

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which occurred in Staffordshire, I am indebted to my friend John Petherick, Esq., Secretary of the Rhymney Iron Company:—

"While at the Wednesbury Old Park Iron works in the year 1836, I was informed by a pitman of the name of William Davis, who had been employed there for many years, and who was a man of considerable intelligence and worthy of confidence, that he had witnessed the following remarkable fact in the working out of a set of veins of ironstone, to embrace the whole of which the mine workings were carried nearly seven feet in height. The workings being entirely carried on upon the 'long-work' system, the whole of the mineral was extracted without leaving any pillars, but the mine rubbish being turned back and 'gobbed up,' quite filled the excavation, as close as it could be packed, to the roof. About two years after this range of the mine had been worked, it became necessary to drive across the old workings for air, when it was discovered that the pressure of the superincumbent strata had been so great as to squeeze down the mine-rubbish originally stowed away *seven feet high* to only *two feet in thickness*, and the effect produced on the rubbish itself was, that it presented the appearance of one entire *mass of rock*, and was so hard that the miners were obliged *to blast it with powder* in order to drive through it."

resulted. It should be stated that in larger works the following theoretical views would be more appropriately introduced as *deductions from facts*, and a contrary mode is here adopted as a matter of convenience only.

It is evident, from what has been before stated, that *oceanic* agency on the one hand, and *volcanic* agency on the other, have been extensively employed in giving the earth its present form and structure. The volcanic agency here alluded to must not, however, be confounded with that which is *now* in action; although perhaps the same in kind, it was more intense in power, and infinitely more extensive in operation. It would appear indeed highly probable that one of the original conditions of the globe was no other than a fused mass of volcanic matter, destitute both of life and organization, and evidently in a state to preclude the possibility of the existence of either till it had undergone great and long-continued modification; or, should we carry our ideas still further back, to a period

> "Ere Time intruded on the silent reign
> Of vast eternity,"—

we may contemplate the primeval state of our planet as a wide extended vaporous mass similar in its nature and appearance to the *nebulæ* which now engage the attention of astronomers. The former existence of heat sufficient to fuse the materials of the globe appears well attested by geological phenomena; and, should a still greater degree have prevailed, which seems by no means improbable, a nebulous condition must have been the result. Subsequently to the remote period, when the nebular mass was condensed into its present spheroidal form, but still intensely heated, "dark illimitable ocean, without bound," appears to have prevailed over the face of the globe, in the midst of which at intervals abrupt insular masses and mountain-chains were upheaved from below by internal convulsions of the heated mass. The consequent agitation of the ocean, and the gradual action of atmospheric agency, wearing away these elevated masses, appear to have given rise to the earlier *sedimentary deposits*, or those resting immediately on the unstratified rocks, which are themselves portions of original volcanic matter. Similar processes appear to have continued through a long succession of ages, internal convulsions, regulated probably by unknown causes, elevating from time to time the original insulated masses, together with new and more extended tracts, which would now consist partly of volcanic or *unstratified*, and partly of sedimentary or *stratified*, masses. In this manner fresh lines of coast would be continually presented to the action of the agitated waters, and the rivers which would then become necessary to drain these tracts of dry land would afford ample materials for new sedimentary deposits, some of which would still be oceanic; while, as the earth slowly approximated towards its present configuration, others would originate, as now, in lakes and estuaries. Thus, in process of time, the original mountain-peaks and chains would become mantled around and partially concealed by their present thick covering of stratified deposits.

While these changes were going on, the earth appears to have received life and organization in proportion as it became fitted for its development. As the ocean originally prevailed, so corals, shells, and marine animals, appear to have been the earliest inhabitants of the globe, their mineralized remains being found abundantly entombed among the lowest, and consequently oldest, fossilliferous strata. As the earth gradually advanced towards its present state, corresponding changes of organization appear to have taken place. Thus, as the continents gradually arose, they became covered by luxuriant vegetation—as lakes and æstuaries were formed, they became tenanted by enormous reptiles and amphibious animals. As the continents and islands became more extended and more elevated, as, in fact, they approximated more nearly to their present state, land animals were introduced; and on the earth's at length attaining the configuration which now exists, those forms of animal and vegetable life which we see around us had by slow degrees been placed upon its surface, and *Man*, of whose existence no previous trace can be found, appears finally to have issued from the hands of his Creator.

The stratified portion of the earth's crust having been deposited by water, *stratum super stratum*, and different organized beings having existed at successive periods, it follows that, independently of the age deduced from *superposition*, a relative antiquity is assignable to each stratum, dependent on the nature of the fossils found in it, or the races of animals and vegetables which were co-existent at the period of its original formation—a geological fact of great importance, as contemporaneous strata are by no means coextensive with each other, and in many cases, therefore, can only be identified by the fossils which they contain. These successive creations of organized beings, each subsequently buried in the sedimentary strata of their own epoch, will at once explain the prevalence of certain fossils in certain rocks, a fact previously noticed.

Supposing the earth to have been originally a fused mass which has cooled down, and by the operations above described been gradually enveloped by accumulations of earthy matter, arising from sedimentary deposition, all of which are very imperfect conductors of heat, it will follow that the general climate, or rather *temperature*, of the globe must have altered much during this process of refrigeration. In the first place, this temperature must have been very high, and in great measure independent of the solar influence, while every successive change must have diminished the effects of central heat; and, as this internal temperature was withdrawn, climate as it *now exists*, or the heat of the sun modified by the external circumstances of the globe, would be progressively developed.

That such has actually been the case appears to be well established. The lower fossilliferous strata indicate by their organic remains, both animal and vegetable, the existence of a very high temperature, presenting forms closely analogous to those which we now find to prevail only in tropical regions. Guided by the same principle, we find a great diminution of temperature in the higher fossilliferous strata, and in the highest and most recent probably an identity of climate with that now existing.

While the stratified crust of the globe was thus gradually forming beneath the primeval ocean, we have abundant evidence that various portions of it were often elevated and thrown into inclined and contorted positions, by lines of volcanic eruption issuing from beneath, and forming the nucleus of some of our present mountain-chains. Subsequently to these movements pyrogenous masses of less magnitude, but still far more abundant and extensive than those produced by existing volcanoes, were frequently thrown up from the interior of the globe, shattering and dislocating the stratified deposits, and often filling up the rents and chasms thus formed (as already noticed in the case of basalt) with fused matter.

This matter has sometimes spread out in vast sheets, resembling modern lava-currents, which have again been covered by sedimentary strata, of which we have an example in the "*toad-stone*" of Derbyshire. In other cases it has been poured out, and accumulated in enormous masses, on the existing surface of the globe, which has happened with the basaltic rocks near Dudley, in Staffordshire, and those forming Arthur's Seat, Salisbury crags, and other eminences near Edinburgh.

It is to these great volcanic movements that the inclined position of the stratified rocks before noticed is in most cases owing, and also those singular dislocations and contortions which in some places disturb their original regularity of position; for matter deposited by water cannot, excepting in certain very rare cases, assume any other than a horizontal, or very nearly horizontal, arrangement. It is also to the proximity of vast masses of intensely-heated volcanic matter that the induration and crystalline structure of the *stratified* rocks, near their contact with the *unstratified* rocks, is owing, a partial fusion and re-arrangement of particles having been thus produced.

We have now briefly and hastily traced the nature of those changes which appear to have acted at remote periods on the crust of the globe, and from which have resulted the beautiful variety and adaptation of its surface which we now behold, changes by which it has been made subservient to the wants and habits of the innumerable organized beings which now inhabit it, and more especially fitted for the human race.

When the stupendous agents then in action had accomplished their destined purpose in producing the lofty mountain stored with mineral treasures, the gentle undulation of hill and dale covered with rich sedimentary soil, the extent of dry land required for the habitation of man, with all the numerous adaptations to the support of life and vegetation which we find around us—when all these ends had been accomplished, a *state of equilibrium* appears to have ensued. Volcanic action now became confined to a comparatively few points, the craters of existing volcanoes, in which it still continues to act, but with greatly-diminished energy. The ocean appears also to have been restrained within its present limits, with the exception of small and local variations, which will be hereafter noticed.

There are, however, decisive indications, that large portions of the surface of the globe have been many times subjected to great irruptions of water, one of which has probably occurred subsequently to this period—revolutions largely fatal to animal life, and which may even in some degree have altered the aspect of the earth's surface, although perfectly distinct from those preceding revolutions by which that surface was formed.

These tremendous irruptions of water have strewed almost every portion of the earth's surface with a superficial covering, formed by the promiscuous ruin of all the various rocks of which that surface is composed. This covering, which will hereafter be described, is generally termed "*diluvium*" by geologists, and we have examples of it in the superficial beds of sand and gravel occurring in most parts of England, and often containing numerous bones and teeth of land-animals, as the elephant, rhinoceros, hippopotamus, &c. These animals must have inhabited the globe at the period these great catastrophes occurred, and have been destroyed by them, their remains being entombed in the ruins thus created, and deposited, together with that ruin, in a general covering over our plains and valleys.

One of these great events may reasonably be considered as identical with the Mosaic deluge, so fully do the records of nature and of revelation agree in attesting a comparatively recent and temporary submersion of a large portion of the globe by water. Among the geological monuments of such events, what are termed "*bone-caverns*" are remarkable for the clear and satisfactory evidence they afford on the subject. These caverns occur in England, in various parts of the Continent, and even in Australia and America, presenting in each of those localities very similar appearances, of bones, some entire, some rolled and gnawed, imbedded in a sedimentary deposit, and sometimes covered by a stalagmitic incrustation. The researches of Dr. Buckland, and other naturalists, who have examined them with attention, prove that these caverns must for a long period have been the dens of antediluvian animals, who perished by a sudden irruption of water into them, the same irruption having often washed in mud, sand, and pebbles, in such quantity as partly to fill the cavern, and on consolidating to envelop the bones in a hard solid mass.

AGREEMENT OF GEOLOGICAL FACTS WITH SCRIPTURE.—On thus tracing the early history and revolutions of our planet, from the physical proofs indelibly engraved on the massive fabric of the globe itself, it becomes a subject of equal interest and importance to compare this record with the only one which, till a very late period, mankind possessed, that of the inspired historian.

However inadequate our limits may be to the discussion of this very difficult and delicate question, it ought not to be passed over in total silence.

Four points of the physical history of the earth are involved in the Mosaic narrative. These are the successive steps of creation; the time employed in these operations; the age of the world *since* that period; the catastrophe of the deluge.

On three of these points the agreement of natural records with those of revelation is decided and unequivocal. The successive steps of creation, both as regards the framework of the globe itself, and the development of organic existence upon it—these, whether deduced from the language of nature or of revelation, are the same. The age of the world, subsequently to assuming its present condition, appears from the inspired writings to be about six thousand years, and the voice of natural records (for the earth bears marks of her own antiquity) speaks the same language. The physical proofs of diluvial catastrophes have already been noticed at sufficient length to show that the fact coincides with the Mosaic narrative.

One point then, and one only, remains open for discussion: we are told by Moses that the earth was *created* (or brought into its present state) *in six days*, while geological phenomena, in the most impressive and unequivocal language, indicate a lapse of time for which no period can be fixed, but in the contemplation of which, as in that of infinite space, the mind is overwhelmed in unappreciable vastness. Hence then arises the question—and, if calmly and dispassionately viewed, it is perhaps a simple one—Are the "*days*" of Moses literally to be understood as days of twenty-four hours?

A discussion on this subject would here be out of place; yet we would observe that both the natural day and the week of seven days are merely periods adapted to the constitution and physical wants of man, and therefore *previous to his existence* were unnecessary, and could have answered no end. Is it not therefore reasonable to suppose that the *days of creation* were merely intended as *types* of those afterwards established, without any reference to their *actual duration?*

When we consider that the sole office of these periods, denominated "*days*," was to estimate the operations of a Being, "in whose sight a thousand years are but as yesterday," may we not, without violation of Scripture, look upon them as those periods of vast and indefinite duration which are pointed out to us by geological phenomena? If this point be conceded, the discrepancy long supposed to exist between geological science and revelation is at once annihilated, and, on the contrary, the strictest harmony will be found to prevail.

CHANGES OF THE EARTH'S SURFACE NOW IN OPERATION.

It is necessary to observe that many physical changes are even now taking place in the surface of the globe, as the same agencies which produced its present structure and configuration are still in action, although with greatly-diminished power, and in most cases a nicely-balanced and compensating effect. Those sedimentary strata produced by causes now in operation are termed "*alluvial deposits*," and, together with modern *volcanic rocks*, of course occupy the highest relative situation of all the materials of the globe.

The agency of the atmosphere, of moisture, and of frost, combine in slowly disintegrating even the most solid and compact rocks of which the surface of the globe is formed, more especially those masses existing in mountainous and elevated situations. The particles thus detached are continually being carried, by the action of rains and torrents, down the sides of mountains, and deposited in valleys, or transported into rivers, whence they are often swept along by the current, and finally deposited near their mouths, in the form of loose sandy beds, or *deltas*, and in many instances wide æstuaries are nearly filled up in this manner, of which the mouths of the Nile and the Ganges afford remarkable examples. The flats formed along rocky coasts by the undermining and wearing away of cliffs, the sands often thrown up along the shore by the sea, and the formation of peat-bogs arising from the growth of mosses and other aquatic plants in lakes and marshy situations, also belong to this class.* These phenomena will now require a more detailed examination.

CHANGES PRODUCED BY AQUEOUS ACTION.—The changes of the earth's surface which are produced at the present time by aqueous agency are in certain localities very considerable, and we need not look beyond our own shores for examples of this fact. The numerous sand-banks which obstruct the navigation of the Thames and the Mersey, by accumulating near their mouths, are produced by a deposition of the mud brought down by these rivers, and by matter derived from the wearing away of the cliffs and banks which surround them. The earthy matter thus constantly accumulating is drifted by the set of the tides and currents into certain situations where it is deposited, and thus is formed in most rivers the nucleus of those banks, which, when unchecked in their progress, often form bars across harbours, and become very injurious, if not destructive, to navigation.

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* It need hardly be observed that peat is a substance of great utility as a fuel, in all situations where coal is dear or not readily attainable; a large portion of our labouring population indeed use nothing else. It has also been employed for smelting lead-ore in Lanarkshire, and has been used to a considerable extent for metallurgical purposes in France, where coal is far less abundant than in England. The quantity of peat which exists in this country is immense, more especially on the elevated moorlands of the West and North of England, of Wales, and Scotland, and many parts of Ireland, in all of which it is found upon the surface in beds many feet in thickness. A machine has lately been invented by Lord Willoughby d'Eresby which promises greatly to extend the use of this fuel, as, by the simple application of pressure, it speedily squeezes out the moisture, leaving the peat in a firm compressed state much better adapted for burning than before, and saves in addition the long and tedious process of drying in the sun, which has always hitherto been necessary. Peat is a spongy mass of vegetable substance, which is generally saturated with moisture, and intermixed with a little earthy matter. Coal, in its original state, was doubtless a very similar substance.

ALLUVIAL DELTAS.—On the continent of Europe, where the rivers are of so much larger size than in this country, similar effects may be witnessed on a far more extensive scale: thus, on the coast of Holland, the traveller cannot fail to be struck with the vast accumulation of alluvial matter which is brought down by the rivers through which the Rhine discharges itself into the sea. Sand-banks are thus formed, which for a considerable distance fringe the coast of that country, and may in time add a considerable extent of territory to it.

Many examples of the power of aqueous deposition in altering the earth's surface are given by Cuvier, in his admirable "Discourse on the Revolutions of the Surface of the Globe,"* one or two of which may complete our view of the subject, by forcibly exemplifying the formation of new lands even in the present state of the globe. "Many cities which at well-known periods of history were flourishing sea-ports are now several leagues inland, and many have even been ruined in consequence of this change of situation. Venice can scarcely preserve the *lagoons* which separate her from the continent; and, in spite of every exertion, she will one day become united to the main land." The same writer observes that "Adria in Lombardy, which conferred its title on the (Adriatic) sea, of which it formed, for more than twenty centuries, the principal port, is now six leagues distant from it." The growth of the alluvial delta of the Nile is highly interesting, and, from this country having formed the earliest seat of civilization, and from the numerous ancient monuments of Egypt being mostly situated on the alluvial soil formed by the Nile, the alteration of the surface admits of being accurately traced from a very remote period. On this subject Cuvier remarks, "the height of the soil of Egypt is produced at the same time as the extension of its surface, and the bottom of the bed of the river is elevated in proportion to the adjacent plains, whence the inundation of every succeeding century much exceeds the height of the marks left by the preceding ones. According to Herodotus, a lapse of nine hundred years was sufficient to establish a difference in the level, of seven or eight cubits (ten or twelve feet). At Elephantia the inundation now reaches seven feet higher than during the reign of Septimus Severus, at the beginning of the third century. At Cairo, before it is deemed sufficient for the purpose of irrigating the lands, it must attain a height of three feet and a half more than was requisite in the ninth century. The ancient monuments of this country are are all more or less enveloped in the soil. The mud left by the river even covers the small artificial hills on which the ancient cities were founded to a depth of several feet."

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* A translation of this work has been published by Messrs. Whittaker.

UNDERMINING OF CLIFFS.—While aqueous agency is thus continually employed in forming new lands in some situations, it is no less active in the destruction of existing shores in others. Wherever the coast is bounded by steep cliffs, they are continually being undermined by the action of the sea: large masses thus fall down at intervals; and, where the material is soft, as clay or chalk, considerable changes are often effected in the configuration of the shore. Examples of this kind may be found in the cliffs bordering the Isle of Sheppy, the Isle of Thanet, and other parts of the Kentish coast, where the two conspicuous towers called the Reculvers, formerly far inland,* are now on the brink of the cliff, and will at no distant period be entirely washed away. The soft friable cliffs on the coast of Norfolk present similar examples of the wearing away of the coast, and the encroachment of the sea. Where the coast is composed of hard rocky materials, as in Cornwall, Devonshire, Wales, and Scotland, or many parts of the Irish coast, the inroads of the sea are of course less striking, but even here they are still perceptible. On walking underneath these cliffs we shall see enormous masses of rock lying on the beach, which have been detached from the precipices above, while thousands of smooth and rounded pebbles, with others still sharp and angular, proclaim the further action of the sea in wearing and disintegrating those masses which are brought within reach of the waves.

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* In the early part of the sixteenth century the distance was nearly a mile.

DRIFTED SANDS.—It would far exceed our limits to trace minutely all the various causes which are perpetually modifying certain portions of the earth's surface, further than appears requisite to the perfect illustration of ancient geological phenomena: with two or three further examples, therefore, we shall conclude. In cases where sandy shores occur, but little elevated above the sea, the waves often force up enormous ridges of loose sand, along the coast, which are drifted inland by the winds, and gradually spread like a torrent over the adjacent country. The most striking example of this phenomenon in Europe is to be found in the drifted sands which are spread over the French coast, along a portion of the Bay of Biscay, and which have not only inundated and destroyed a large tract of country within the period of recorded history, but are still advancing at the average rate of from sixty to seventy feet per annum, threatening to envelop numerous farms and villages in the same overwhelming destruction which many within the last few centuries have already shared. The shifting sands of the Libyan desert, which are spread by the set of the winds over the fertile soil of Egypt, enveloping towns and villages in a gradual but irresistible destruction, afford another striking example of the phenomenon under consideration.

The north coast of Cornwall, more especially in the neighbourhood of Hayle and Perranzabuloe, exhibits an interesting example of the progress of drifted sands. Those parts which I have examined consist of a range of sandhills not less than 50 or 60 feet in height, loos and shifting in their nature, and apparently derived in great measure from the finely-comminuted fragments of innumerable sea-shells. The tops of houses and churches buried centuries ago are occasionally visible through the mass, the further progress of which has fortunately been arrested by covering and fixing the soil with that useful plant, the *Arundo arenaria.*

Dr. Paris has noticed on some parts of this coast the singular phenomenon of the formation of recent *calcareous sandstone;* the loose sands, owing to the action of cementing matter, actually passing in some places into a hard compact rock.

RAISED BEACHES—SUBMARINE FORESTS—LITTORAL DEPOSITS.—A very remarkable class of phenomena which are observed upon many parts of the shores both of our own and other countries, may here be introduced as among the more recent changes affecting lines of sea-coast, which, it will be seen, are even now greatly subject to alteration—raised beaches, submarine forests, and littoral depositions.

Since the attention of geologists has been drawn to the subject of *raised beaches*, a great deal of curious evidence has been accumulated on the subject, proving that this phenomenon is by no means of rare occurrence, and that in many cases ancient beaches, precisely similar to those now washed by the sea, are to be found at some distance from it, and often at an elevation of many feet (in some cases as much as 30 or 40) above it. A raised beach of this kind near Brighton has been described by Dr. Mantell; others have been found on the coast of Devonshire, near Plymouth, on the coast of Cornwall, and on the Frith of Forth. This phenomenon has doubtless been produced by an elevation of the adjacent land, either during ancient earthquakes, or by a slow and imperceptible expansion of the crust of the globe, which will be noticed under the head of volcanic changes.

Submarine forests are those accumulations of peat, vegetable matter, and trunks of trees, often partially buried in mud and silt which occur on many parts of the coast, and which indicate the growth of ancient forests in situations now submerged at high water. A forest of this kind may be traced along the Thames, commencing at the Isle of Dogs, and extending for many miles down the river. Submarine forests occur also near the mouth of the Parret in Somersetshire, and along the low marshy coasts of Lincolnshire and Lancashire, and in many similar situations. In some cases they may perhaps be referred to a depression of the land, and in others may admit of explanation merely from a change in the configuration of the coast allowing the sea to spread further inland than formerly.

Littoral depositions form an important class of alluvial phenomena, and may be considered as a compensating agency for the gradual wasting and undermining of cliffs before noticed. In situations where soft friable cliffs are continually being washed away by the sea a fine sediment is the result, which is drifted along the coast by tides and currents to some shallow bay or æstuary, on the marshy shores of which it is deposited, forming a slow, but, in the lapse of ages, an important addition to them. The effects produced by this agency in our own country are both striking and important: while, as previously described, those large portions of our coasts which are bounded by cliffs are continually yielding to the encroachments of the sea, we have in other situations large tracts of alluvial land, of comparatively modern growth, and which by draining and embankment have been made to form a permanent and valuable addition to our soil. It is probable that a great deal of the marsh-land about Bridgewater in Somersetshire, of Romney Marsh in Kent, of the fens of Lincolnshire, the marshes bordering on the Humber, and those of the coast of Lancashire, may have been thus originally formed.

PHENOMENA OF VOLCANOES.—The phenomena presented to our notice by volcanoes are of vast interest and importance to the geologist, as they afford a satisfactory explanation of many of the most obscure problems which the internal structure of the earth offers for our solution. The former extensive influence of subterranean heat in modifying the materials of the globe has been already noticed, and we now find in volcanoes the local and expiring action of that tremendous agency which at ancient periods formed the enormous masses of the unstratified rocks, and also shattered, contorted, and indurated the sedimentary strata, as we now find them.

It is well known that volcanoes are generally lofty conical mountains, with one or more deep hollows or depressions on or near their summit, called craters, and that their most characteristic phenomena consist of occasional eruptions, during which torrents of melted matter are ejected from the crater, which, slowly flowing down the sides of the mountain, consolidate into the hard porous rock, termed *lava*. Independently of these obvious and prominent phenomena, there are, however, many others of great geological interest which will here be briefly noticed.

The volcanic orifices with which so many portions of the earth's surface are thickly studded admit of a natural and convenient division into two classes—*active* and *extinct*. The former includes, of course, all those which, like Etna and Vesuvius, are known to exhibit either frequent or occasional paroxysms of volcanic energy; the latter, those which, like the volcanoes of Auvergne and the Eifel, have slumbered from the earliest period of recorded history. The number of active volcanoes has been estimated at about 200; of extinct volcanoes, no estimate has, I believe, been formed, but it must vastly exceed the former, for in the Eifel district alone there are not less than thirty extinct volcanic cones, while in other countries there are groups equally numerous.

of immense masses of rock from the crater, and the showers of volcanic sand and ashes, which are often distributed over a large extent of the surrounding country, not unfrequently at distances of 200 or 300 miles from the volcano. Showers of this kind appear to be nothing more than masses of rocks, which, by repeated projections from the crater, and falling into the abyss below (which if thrown up vertically must continue to receive them), have been reduced to such a state of tenuity, that the rush of vapour finally keeps the mass suspended in the atmosphere to an enormous height, till the upper portion of it drifts away with the wind, and is deposited on reaching a more tranquil region of the atmosphere.

CHANGES OF THE EARTH'S SURFACE PRODUCED BY VOLCANIC ACTION.—The local changes produced by great eruptions are often very considerable, as one or two examples will be sufficient to show. In the celebrated eruption of Skapta Jokul, one of the volcanoes of Iceland, which took place in 1783, two enormous streams of lava flowed in opposite directions from the crater, the one extending *forty* and the other *fifty* miles in length, the breadth varying from seven to fifteen miles. Valleys were thus dammed up, the course of rivers stopped or obstructed, and the face of the country so completely altered and desolated, that thousands of the inhabitants fell victims to this scene of devastation.

An enormous volcano which existed between sixty and seventy years ago in the island of Java furnishes a striking instance of the manner in which volcanic mountains occasionally undermine themselves, and the consequences which may ensue from the continual enlargement of the volcanic orifice, owing to repeated eruptions. During an eruption of this volcano in 1772, the base gave way, and the whole mass of the mountain actually sunk into the earth, being, doubtless, received by the abyss below, which its fury had for ages been hollowing out. The tract of elevated country thus swallowed up has been estimated at no less than *ninety* square miles, and many of the inhabitants fell victims to the catastrophe.

An eruption of the Tomboro volcano in the island of Sumbawa, which took place in 1815, was characterized by extraordinary violence: for *two thousand* miles around it the earth was perceived to undulate, and over the immediate area of several hundred square miles the fury of the eruption was awfully felt and the ground strewed with volcanic ashes.

EXTINCT VOLCANOES.—But little need be said on the subject of extinct volcanoes, as the external phenomena they present are in close accordance with those of active ones, although the exciting causes have been long wanting, by which their paroxysmal energies were aroused. In extinct volcanoes the cones, the craters, and the streams of lava, after a lapse of unnumbered ages, still remain perfect, and even showers of sand and pumice may still be traced. In the group of extinct volcanoes which borders on the Rhine, it is remarkable that some of the volcanic orifices appear to have given vent to gaseous explosions rather than to lava-currents. In one which I examined no traces of streams of lava were visible on the sides, although large masses of it were lying on the summit, especially at one point, from which an eruption appeared to have broken forth. Everything indeed seemed to countenance the idea that eruptions, of gaseous matter, accompanied merely by occasional *jets* of lava, had formed the phenomena of this volcano; and I may further observe that the patches of loose pumice which are occasionally exposed to view in the road-cuttings of this part of Germany strongly indicate the ancient prevalence of gaseous eruptions and their usual concomitants, showers of volcanic ashes. Many of the Eifel craters, as well as those of Auvergne, are in a very perfect state, and exhibit streams of lava and every external volcanic appearance which is to be seen in active volcanoes, excepting actual eruption.

Recent and submarine volcanoes.—While Nature presents us on the one hand with volcanic orifices, which at greater or less intervals have been characterized by eruptions through the whole period of recorded history, and on the other with numberless volcanoes which have been extinct from the remotest period, and which, although perfect and entire, as if the subterranean fire had broke forth but yesterday, have in all probability slumbered from a period antecedent to the existence of the human race, she also occasionally affords us the magnificent phenomenon of the bursting forth of new volcanic vents. Thus, volcanic phenomena are presented to our view under the three striking phases of extinct volcanoes, the outlets of subterranean fire, long since dormant or choked up and transferred to other vents; of active volcanoes, the energy of which is of a permanent character; and of recent volcanoes, which appear to break through the weaker parts of the earth's crust, affording vent to new localities of subterranean disturbance.

It is remarkable that recent volcanoes generally burst forth from the bottom of the sea, thus elevating volcanic cones, or in some cases permanent islands, above the surface, for, owing to the looseness of their texture and the incessant action of the waves, the former are frequently washed away, and leave no traces of their existence beyond a shoal. The Mediterranean has been remarkable from the remotest times for the emergence of submarine volcanoes, an example of which occurred so lately as the year 1831. The elevation of Monte Nuovo, a volcanic island 440 feet in height, and a mile and a half in circumference, which took place in 1538, affords another well-known example of recent volcanic action.

Perhaps the most striking instance of the bursting forth of a new volcanic vent in recent times is afforded by the elevation of the volcano of Jorullo in Mexico, which took place in an inland situation in the year 1759. Earthquakes and frightful subterranean sounds long preceded this great catastrophe, and gave notice to the inhabitants of a fruitful and cultivated plain that some great internal convulsion was about to happen, and thus allowed of their escape to the neighbouring mountains, from whence the scene was witnessed by many in all its grandeur. On the night of the 28th September the crisis took place: "a tract of country from three to four square miles in extent rose up like a bladder,"* attaining towards the centre an elevation of 524 feet, and covered by thousands of small cones emitting columns of thick vapour to the height of forty or fifty feet. From a chasm crossing this elevated tract, six volcanic masses were thrown up, varying from 1300 to 1600 feet above the level of the plain, the highest being the great volcanic orifice termed the volcano of Jorullo, which continued in a state of activity for about six months, and is still burning. When this spot was visited by Humboldt, about forty years after the event, he found that the thermometer in the shade, and at a great distance from the surface, rose to 109° Fahr., while two rivers, which had been swallowed up by the eruption, rose again from under the elevated mass, as mineral waters, having a temperature of 126° Fahr., thus confirming the account given by many of the old Indians, who affirmed "that, for many years after the first eruption, the plains of Jorullo, even at a great distance from the scene of the explosion, were rendered uninhabitable from the excessive heat which prevailed in them." To these well-authenticated facts, establishing a long-continued elevation of temperature in the vicinity of volcanic action, I would direct the particular attention of the reader, as closely connected with the theoretical explanation previously given of the former high temperature of the surface of the

* Humboldt.

globe, arising from its greater proximity to the heated internal mass.

EARTHQUAKES.—Earthquakes are those tremulous motions of the earth's surface which are often experienced not only in the vicinity of volcanoes, and in evident connexion with them, but also in parts of the world far removed from volcanic action. The intensity of earthquakes varies greatly: in their most gentle form they occasion merely a slight undulation of the ground, which is frequently repeated at irregular intervals; when more violent the earth is agitated in a most extraordinary manner, not unlike the rolling of a vessel at sea; it is elevated in some places and depressed in others, and, when the tension of the strata is extremely violent, rents and fissures are sometimes occasioned.

The extensive area over which the shock of earthquakes is often felt is very remarkable, and satisfactorily demonstrates the enormous depth at which the disturbing force must operate. Tracts of country 1000 or 1200 miles in extent are not unfrequently simultaneously convulsed, and the shock of an earthquake has even been known to pass beneath the broad expanse of the Atlantic, and to affect alike the shores of Europe and America.

THEIR PERMANENT EFFECTS.—The permanent elevation or depression of land during earthquakes is also an important fact in a geological point of view: the best-authenticated instance of the former is that which occurred on the coast of Chili in 1822, when it appears that for an extent of about 100 miles the coast received an additional elevation of about four feet above the sea-level. An instance of the depression of the land occurred during the terrible earthquake which, in 1692, destroyed Port Royal in Jamaica, when the site of that unfortunate town was permanently submerged below the sea, partly by a settlement of the sands on which it was built, and partly, no doubt, by an actual subsidence of the land.

THEORETICAL VIEWS.—Earthquakes are generally regarded as modifications of volcanic agency, phenomena of both classes being connected with the heated state of the earth's internal mass, and the intense chemical action and consequent disengagement of elastic vapours, which appears to prevail at an enormous depth, below a large portion of the earth's surface. We see, in fact, in earthquakes and volcanoes, the modified and repressed action of those mighty forces which at an earlier period of the earth's history produced the vast masses of the unstratified rocks, and elevated them, together with the superincumbent sedimentary strata, from the bosom of the ocean, thus forming our present continents and islands, and giving rise to the configuration of the land which now exists.

Although severe shocks from earthquakes are not of very frequent occurrence, there are many parts of the world in which slight vibrations of this kind are by no means uncommon, and to which they are chiefly confined. The phenomenon appears, indeed, to be very much of a local character, the area over which it is felt (sometimes of immense extent) being in great measure proportioned to the intensity of the shock. The West Indies are well known to be frequently visited by earthquakes, and in Europe the undulations are often felt in Portugal and sometimes very feebly on the south coast of England. Perhaps beneath these tracts there may be weak portions of the earth's crust, through which the undulations of deeply-seated incandescent or gaseous matter may be conveyed more readily than elsewhere. I have been favoured by a valued friend with the particulars given in the subjoined note,* of an earthquake which was felt at Lis-

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[*] “One of the severest shocks of an earthquake which has been experienced in Europe since the celebrated one which, in 1755, destroyed the city of Lisbon, was on the night, or rather morning, of February 2nd, 1816. I had retired to bed about an hour before the shock commenced, and was awakened by a tremulous motion occasioning the bed to rise and fall as if some person were underneath it, which was indeed my first impression. The first three or four shocks appeared to be vertical, and the whole house was in motion, every timber straining, as a ship labouring in a heavy sea, the houses in Lisbon being peculiarly constructed within a wooden frame-work, to enable them to withstand the frequent shocks of earthquakes which are experienced there. On rising, I found all persons in great consternation, ‘miserecordia’ and other pious ejaculations being heard on all sides. The duration of the shock was estimated at about a minute and a half, being much longer than that of any single shock for a considerable period; indeed, the present one was more remarkable from its length than from its violence. Two very short but more violent shocks were felt about four or five hours afterwards, which lasted for a few seconds only, but the damage done on this occasion was very trivial. The day previous had been heavy and close, and

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bon in 1816, which will convey a very accurate idea of the ordinary sensations which are experienced on these occasions.

Coral reefs.—One of the most curious, and in tropical seas not the least important, agents concerned in the changes of the earth's surface now in progress,

immediately after the first shock the rain descended in torrents: a slight rumbling sound was heard during the undulations.

"In the logbooks of different vessels which arrived at Lisbon during some days afterwards, notice was taken of a shock experienced at sea, corresponding in time to the first shock above described; and in the logbook of one vessel, coming from Madeira, which arrived several days subsequently, the captain having described the shock, and stated that all hands were turned out and the lead hove, apprehending that the vessel had struck, goes on to surmise, having satisfied himself that he was in deep water, and at a distance of some hundred miles from the coast of Portugal, that an earthquake had, probably, occurred at Lisbon.

"This earthquake was not felt in Cadiz to the south-east of Lisbon, and hardly at all in Oporto, which lies nearly to the north. It seemed from Lisbon to take a direction from the coast more to the interior, and was traceable at intervals to the very base of the Pyrenees, having in its course nearly destroyed a small Portuguese village.

"During a residence of nearly six years at Lisbon I experienced several slight shocks, which to an inexperienced person would hardly have been perceptible, being nothing more than the sensation produced by a heavy waggon rumbling past, and which would have passed for such, only that no waggon or other cause was near to produce the effect. The natives consider frequent slight shocks to be almost a guarantee against any severe one: this theory they have probably deduced from experience."

is the growth of coral reefs. These reefs are the work of millions of zoophytes, and in some cases extend hundreds of miles in length, forming new islands, perhaps hereafter to be inhabited by man. This process is the more interesting, as many of the ancient strata of the globe appear to have been formed by similar agency.

It was formerly supposed, but very erroneously, that corals commenced their reefs at great depths below the surface of the ocean, a mistake probably occasioned by deep soundings being often found in the immediate vicinity of coral islands. It is now, however, well ascertained that they build in water of moderate depth only, and that the situations chosen are frequently the summits and craters of submarine volcanoes, a circumstance which often occasions coral islands to assume a very remarkable outline. The corals discontinue their labours on reaching the surface of the water, but the sand and drifted matter continually thrown by the sea upon these reefs has the effect of elevating them somewhat higher, and also forms in time a vegetable soil, which the dispersion of a few accidental seeds, under the influence of a tropical sun, in time covers with luxuriant vegetation. Many important islands have been formed by this singular agency, and the alterations which it is now producing in tropical seas, especially in the Pacific Ocean, are very considerable. It is deserving of remark that in coral islands we are presented with a combination of the three great agents which have given the earth's surface its present configuration.

Volcanic action elevated the submarine peak, organic or vital agency invested it with its upper calcareous crust, while aqueous deposition bestowed its covering of vegetable soil.

As any lengthened detail of geological theory, however valuable in itself, would be entirely inconsistent with the plan of the present work, the preceding facts, illustrating the nature and effects of those great agents which have been employed in giving the materials of the globe their present form and arrangement, have therefore been given so fully that the reader may thence deduce many conclusions for himself and perceive at once the grounds on which the most important theoretical deductions of geology are built. Some few of these it must be admitted are still uncertain, and may long continue to form subjects for discussion. Those, however, which are most important, as standing at the very threshold of geological inquiry, may now be looked upon as immoveably established, and as having passed from being mere matters of opinion, into the list of universally-admitted truths.

PRACTICAL VALUE OF THESE FACTS.—A correct knowledge of those changes which are actually taking place on the surface of the globe not only furnishes us with a key to more ancient phenomena of the same kind, and explains the nature and operation of those geological causes which, by gradually modifying the earth's surface, have produced its present structure and configuration, but it is of great service in other points of view, and often admits of practical applications by the engineer. Thus, by observing the mode in which nature operates in the filling up of estuaries and harbours, or throwing bars across the mouths of rivers, by correctly appreciating the causes which lead to these obstructions, we are furnished with the readiest modes of lessening or counteracting the evil. Where rich alluvial lands are forming along the coast, the operations of nature may often be assisted by art, the wearing away of cliffs may also be in some cases diminished, and valuable land preserved, while even the progress of drifted sands may often be checked by timely and judicious planting. A knowledge of the formation both of sand-banks and of coral reefs cannot be otherwise than useful to the navigator, nor can he but feel interested in those great movements of the earth's surface which, either as earthquakes or sub-marine volcanoes, often effect permanent changes in the bed of the sea, and alter those soundings on which he had formerly depended for guidance.

LIMITATION OF EXISTING CHANGES.—While pointing out the great fluctuations of the earth's surface which are now in progress, it is also necessary to direct attention to the fact that, however extensive, they are in great measute confined to certain tracts, and that a large portion of the globe is almost exempt from their action. Thus volcanic eruptions and earthquakes chiefly prevail around certain centres and lines of subterranean disturbance, while the action of the sea and rivers is limited to coasts and estuaries, and only under certain conditions is capable of effecting extensive changes. Atmospheric agency embraces of course a wider sphere of operation, since it is co-extensive with the solid mass of the globe, yet over a large portion of the land its action is completely nullified by the mantle of vegetation which covers and protects the soil.

FLUCTUATIONS IN THE LEVEL OF THE LAND.—With a brief notice of one other existing cause of change, the consideration of the present subject may be concluded. An opinion has long been entertained that the relative level of the land and water is not in all cases permanent, in other words, that the land is on some coasts in a state of very gradual, but still perceptible, elevation, while in others a slow depression is taking place. This opinion has within the last few years been examined and confirmed by Mr. Lyell, who has investigated the subject with great precision and acuteness. He has demonstrated that the countries adjacent to the Baltic are in a state of gradual elevation, that the rise may be estimated at about two or three feet in a century, and that the coast of Greenland is experiencing, on the contrary, a slow depression. These changes of level are not due to the direct action of earthquakes or volcanoes; they can only be satisfactorily explained by supposing a slow refrigeration of the earth's crust in some places, and a local increase of temperature in others; the former being of course accompanied by a gradual contraction, and the latter by a slow expansion of the mass—an explanation perfectly consistent with ascertained principles, and, indeed, the whole range of geological phenomena. A beautiful example both of elevation and subsidence of the earth's surface, within the historical period, is afforded by the ruins of the temple of Jupiter Serapis, described by Mr. Lyell in his Principles of Geology.

CLASSIFICATION OF ROCKS.

From the brief review which has now been given, both of the leading facts and theoretical conclusions of geology, it will be readily seen that the principal objects of this science must be to arrange and classify the stratified and other masses constituting the exterior of the globe, to determine in what order they have been placed by nature, and to investigate their composition and structure, and the various phenomena by which they are individually characterised, as well as the changes and revolutions of the earth's surface which are thus indicated. The latter object can, of course, only be effected by a careful study of the *present* economy of nature, and rigid attention to those changes which are *now* in operation, of which a brief sketch has just been given.

In order to accomplish these objects, it becomes necessary, as far as possible, to generalise and group together the individual strata (themselves practically innumerable) which form the stratified class of rocks before mentioned, and by this means to bring their otherwise unwieldy number within convenient limits for practical consideration. Thus, whenever a series of beds is found constantly associated together in the same order, and possessing certain general characters of agreement, either as regards their mineral composition, or the fossils they contain, they are classed together under the name of a "*formation*." Thus we have the *chalk formation*, the *coal formation*, &c., terms which conveniently express a large assemblage of mineral strata.

By following the same method with respect to formations themselves, we are enabled to arrive at a still more general and comprehensive classification—that of *primary*, *transition*, *secondary*, and *tertiary*, formations. This is an arrangement very generally followed by geological writers, although by many the transition class has been abolished, and grouped with the secondary.

The distinguishing characters of these four great classes of rocks may thus shortly be described. On taking a general view of the whole mass of stratified deposits, it was found by geologists that a large number of those occupying the *lowest relative position in the series*, or resting immediately upon the unstratified rocks, exhibited certain peculiarities, distinguishing them in a striking manner from the rest. These peculiarities consist in a compact and crystalline texture, apparently the result of chemical affinity, in the total absence of the remains of organized bodies, and also of imbedded fragments or pebbles derived from other pre-existing rocks. These characters, together with the circumstance of the rocks possessing them always occurring *below*, but never *above*, those distinguished by an opposite character, naturally led to the inference that they were not only of an older date, but that they were formed at a period antecedent to the existence of organized beings upon the globe. From these considerations this class of rocks received the name of *primitive*, from the earlier geologists, an appellation which has since been modified into *primary*, the name now generally adopted.

The term *secondary* would, perhaps, strictly speaking, embrace the whole mass of stratified rocks, which are *not* included as *primary*, their characters being in every respect the very reverse of the latter. Thus they are generally of a loose earthy texture, and exhibit but little appearance of crystalline structure. They contain, often in vast profusion, the fossil remains of both animal and vegetable productions, and display the most unequivocal marks of being made up in great measure of pre-existing materials, or the waste and ruin of the subjacent primary strata.

Such are the general characters of the great mass of the secondary strata; but, as further subdivision was considered desirable on the ground of convenience, the class called *transition* was formed out of the *lowest*, and that called *tertiary* out of the *highest*, rocks of the group.

To explain the first of these terms, we may observe that, however distinct the primary and secondary rocks may be in most of their characters, it is often difficult to draw an absolute line of demarcation between them in their natural place, as the lower secondary rocks are frequently *interstratified* with others considerably resembling the primary class, and generally contain organic remains much more sparingly than the rocks above them. To this class, therefore, the name of *transition* was given, as being indicative of their intermediate character, and from the presumption of their having been formed while the earth was passing from a state devoid of organic life into one in which organization became fully developed. The term is however very indefinite, and, as before noticed, is now disused by many geological writers.

On examining with attention the numerous spoils of the animal and vegetable kingdom, which characterise the secondary group of rocks, it was soon discovered that a large proportion of them belonged to species *entirely unknown in a recent state*, and which appear successively to have been created, and to have been destroyed, during the early revolutions of the globe. It was also found that some of the uppermost and consequently most recent of the secondary rocks contained fossil remains, *not differing from those forms of organic life which are now in existence.* The name *tertiary* was then given to the strata containing the latter, while that of *secondary* was retained for that lower class of rocks in which fossils belonging to *extinct species only* are known to occur.

It will thus be seen that each of the great classes of stratified rocks has been built up with regularity, and has a certain relative position of its own, the primary always occurring lowest, and the transition, secondary, and tertiary, being respectively next in the order of superposition. With regard to the unstratified rocks, however, this regularity of position prevails in a much less degree, (as might indeed be inferred from their volcanic origin,) although it may be recognised to a limited extent. These rocks are distributed among all the different classes of stratified rocks, and occur most abundantly in vast masses protruding from below the latter, and supporting them, in which case they are termed *primary unstratified rocks*. They also occur in irregular masses lying upon the stratified rocks, but always issuing from below, in very irregular beds protruded between them, or in dykes or channels filling up rents or fissures which have formerly existed in them. Unstratified rocks, when they occur in the three latter modes, are often termed *trap-rocks*, and are much less extensive than those belonging to the primary class.

If to the six great classes of rocks now enumerated we add *diluvial* and *alluvial* deposits, and modern *volcanic* rocks, it will be seen that the whole known materials of the globe are thus reduced within the compass of a convenient and comprehensive classification.

It has been already observed that the external configuration of the earth's surface is closely connected with its internal structure, the hard rocky materials of the globe generally forming abrupt and mountainous districts, while those of a loose earthy nature form low and comparatively level tracts of country. Connecting this circumstance with the classification just described, it may be stated, as a general fact, that it is the primary class of rocks, both stratified and unstratified, together with the transition rocks lying upon them, which throughout the world form the mountainous regions before noticed, while the secondary and tertiary strata form, in like manner, all the lowest and most level portions of the earth's surface.

The mode in which the various classes of rocks are usually found grouped together, and also the manner in which the external features of the earth are affected by its internal structure, will be more clearly understood by reference to the diagram, fig. 1, Plate 2. It may be observed that the unstratified primary rocks often range in vast irregular curved lines, enclosing large areas or *basins*, partially filled up by the stratified class of rocks, a case which actually applies to a large portion of Europe. The diagram represents therefore a section taken across an area of this kind, and crossing the enclosing unstratified rocks, at both extremities.

If we would apply this diagram to the actual structure of any part of the globe, that of Europe for instance, we may consider the elevated primary rocks on the left hand to represent the mountains of Scotland, and those on the right as the Alps and the mountainous regions of Switzerland. The secondary tract of strata will represent a large portion of England, France, and northern Germany, and the small deposits of tertiary strata in the centre will show the *chalk basins*, as they are termed, of London and Paris. The trap-rocks on the one side indicate the position of masses already noticed as existing near Edinburgh, and those on the other, similar masses occurring in Germany.

It is needless to observe on the want of proportion and other defects of this diagram, which is of course merely intended to convey a very general idea of the nature of the earth's structure.

After the preceding general view of geological science, it will now be desirable to proceed more into detail, and in the first place to point out the individual rocks which collectively form the great classes before noticed. This will be most conveniently exhibited by the following tabular view, which shows all the most important rocks of the geological series, with especial reference to the structure of our own country, in which we may consider that series to be very perfectly developed, although we are deficient in some of the upper members of the tertiary class, and also in modern volcanic rocks.

Tabular view of the order of superposition of the principal Formations or Groups of Rocks, both Stratified and Unstratified, beginning with the highest, and, consequently, most recent:—

STRATIFIED ROCKS.	UNSTRATIFIED ROCKS.
Recent Formations.	Modern volcanic rocks, as lava, volcanic ashes, &c.
Alluvial and diluvial deposits.	
Tertiary Formations.	
Upper marine formation { Suffolk crag. Bagshot sand.	
Alternating marine and freshwater deposits.	
London clay, with septaria beds.	
Plastic clay and sandy beds.	
Secondary Formations.	
Chalk { Subdivided into upper and lower chalk and chalk marl.	
Greensand { Subdivided into upper greensand, gault, and lower greensand.	

STRATIFIED ROCKS.		UNSTRATIFIED
Wealden rocks.	Subdivided into Weald clay, Hastings sand, and Purbeck beds.	
Oolitic group	Subdivided into upper, middle, and lower oolite.	
Lias	Subdivided into upper lias shale, marlstone, lower lias shales and limestones.	
New red sandstone	Subdivided into red marl, red sandstone, and conglomerates.	
Magnesian limestone	Subdivided into magnesian limestones, limestone conglomerates, and sandstone beds.	
Transition Formations.		
Coal measures.		Basalt.
Millstone grit series.		
Carboniferous or mountain limestone.		Amygdaloid.
Old red sandstone and flagstone beds.	Subdivided into upper sandstones and conglomerates, marls, limestones, and flags.	
		Greenstone.
Silurian rocks.	Subdivided into Ludlow rocks, Wenlock and Dudley rocks, Horderley and May Hill rocks. Builth and Llandeilo rocks.	Syenite.
Greywacke slate and interstratified transition limestones.		Porphyry.
Primary Formations.		
Primary sandstone.		Diallage rock.
Primary limestone.		
Primary clay-slate.		Serpentine.
Mica-slate.		
Gneiss.		Granite.

In this tabular view only the principal subdivi are noticed.

With regard to the synopsis here given, necessary to observe, that it must not be suppo exhibit the mineral structure of every part of the globe, or even of any particular portion, without considerable modification. It shows, however, the order of the principal groups of stratified rocks in those countries where the series is most perfectly developed, which is the case over a large portion of Europe. In some parts of the world, America for instance, many of these groups are entirely wanting, and even in our own country some of the members are not always present, as in Devonshire and Somersetshire; where the new red sandstone rests immediately on greywacke slate, the whole carboniferous group being either absent or very imperfectly represented, while the Staffordshire coal-measures rest at Dudley upon a transition limestone, their usual substrata, the millstone grit and the carboniferous limestone, not occurring there. The unstratified rocks may be considered as generally occurring among the stratified in an order approaching to that which is here given; the reasons of their irregularity of position will be evident from what has been previously stated of their origin.

PART III.

DESCRIPTIVE GEOLOGY.

Geological Structure of Great Britain—General Description of the most Important Rocks, especially those occurring in Great Britain: Stratified Rocks: General Review—Nature and Arrangement of Facts. Diluvial Deposits: General Views—Examples—Theoretical Views—Fossil Remains—Tertiary Deposits: General Review—Particular Description—Crag—Bagshot Sand—Alternating Marine and Fresh-Water Deposits—London Clay—Plastic Clay—Minerals of Tertiary Strata—Rise of Springs in Tertiary Strata. Secondary Formations: General Views—Chalk Formation—Fossils—Springs, &c.—Inclination — Origin—Minerals — Greensand — Wealden Formation—Oolite Formation—Upper Oolite—Middle Oolite—Lower Oolite—Lias—Fossils—Minerals—New Red Sandstone—Rock Salt, &c.—Local Details—Magnesian Limestone—Coal Formation—Faults—Varieties of Coal—Mineral Structure of the Coal Formation—Its Development in Great Britain—Foreign Localities—Organic Remains—Origin of Coal—Detailed View of the British Coal-fields—Somersetshire Coal-field—Forest of Dean Coal-field—Great South Wales Coal-field—South Staffordshire Coal-field—Flintshire Coal-field—Lancashire Coal-field—Yorkshire, Derbyshire, and Nottinghamshire Coal-field—Whitehaven Coal-field—Durham and Northumberland Coal-field—Great Scotch Coal-fields—Minor Coal-fields of England—Shropshire—Warwickshire—Leicestershire—North Staffordshire, &c.—Culmiferous Deposits of North Devon—Coal-fields of Ireland—Mining in Ireland—Importance of our Coal Deposits—Probable Duration of our Reserves of Coal—Millstone Grit—Carboniferous or Mountain Limestone—Localities—Organic Remains—Mineral Produce—Scenery—Old Red Sandstone—Silurian Rocks—Ludlow Rocks—Wenlock and Dudley Rocks—Horderley and May Hill Rocks—Builth and Llandeilo Rocks—Greywacke and Greywacke Slate—Fossils—Localities—Mineral Produce—Origin—Transition Limestone, or Greywacke Limestone. Primary Rocks: General Views—Primary Sandstone—Primary Limestone—Primary Clay Slate—Mica Slate—Gneiss. Unstratified Rocks: General Views—Modern Volcanic Rocks—Basalt—Fingal's Cave—Giants' Causeway—Amygdaloid—Greenstone—Syenite—Porphyry—Diallage Rock—Serpentine—Granite—Localities—Uses—Mineral Produce.

GEOLOGICAL STRUCTURE OF GREAT BRITAIN.

We may now proceed to consider the individual character of the formations or groups of rocks enumerated in the preceding tabular view; and as in this sketch reference will chiefly be made to their localities and peculiarities within the limits of our own country, a general view of the geological structure of Great Britain will first be desirable.

On examining the internal structure of this country, it will be found that Great Britain offers a very beautiful illustration of the great principles of geology, as it presents a very complete assemblage of rocks, from the most ancient to those of comparatively modern origin, although not the most recent known.

These rocks are also disposed in such a manner as strongly to mark the physical geography of the country; and while our extensive line of sea-coast presents innumerable and beautiful sections of the various rocks and strata, which, after ranging regularly across the island, are terminated in succession by bold cliffs upon our shores, opportunities equally numerous and instructive, for studying the geology of the interior, are afforded by our mountains and valleys, and by our numerous mines and quarries, and the deep cuttings for roads, canals, railways, and other public works. It may further be observed, that no country presents greater inducements for geological study on the grounds of practical utility than are to be found in Great Britain, for in no part of the world does nature appear to have concentrated such vast deposits of mineral wealth within so limited a space. The most valuable of all mineral substances, *coal* and *iron*, we possess in what may almost be termed profuse abundance. *Tin*, *copper*, *lead*, and other metals, are found in enormous quantity; *rock-*

salt and *building-stone* of every variety, from the coarse enduring granite to the finest kinds of ornamental marbles, exist in such quantity as to defy exhaustion.

The general direction of the secondary strata of this country, which form the most regular and striking feature of our stratification, is from *south-west* to *north-east*, and they range thus from the coast of Devonshire and Dorsetshire to that of Yorkshire and Durham, having a general dip or inclination to the *south-eastward*. The formation best known and most easily traced is probably the *chalk*, which, it will also be remembered, forms the uppermost of our secondary strata. This formation ranges in the direction before noticed from the coast of Dorsetshire to that of Yorkshire, and extends in some places quite to our eastern coast, but has two depressions of great extent in its upper surface—the northern and principal one including London and its vicinity, Middlesex, Essex, &c., while the southern one includes part of Hampshire and the Isle of Wight. It is in these hollows, or *basins*, as they are geologically termed, that the tertiary strata of this country are deposited, these groups being respectively denominated the "*London*," and the "*Isle of Wight basin*."

Towards the bottom of the secondary strata is situated one of our most extensive deposits, the *new red sandstone* and its associated *red marl*. This deposit runs north-eastward in a zone parallel to the chalk and subjacent oolitic strata, from the coast of Devonshire to that of Yorkshire and Durham; but about the middle of its course, or in Warwickshire and Leicestershire, it expands into a vast tract occupying a large portion of central England. This tract stretches north-westward over parts of Staffordshire, Shropshire, Cheshire, and Lancashire, to the western coast.

The *coal-measures* and other rocks of the carboniferous series, especially the *mountain limestone* and its associated *shale* and *gritstone*, rise up from beneath the new red sandstone, running in a nearly north and south direction, dividing the two branches before mentioned, and traversing Derbyshire, Yorkshire, and the other northern counties. The coal-measures also rise up, in patches of greater or less extent, from below the secondary strata, in Somersetshire, South Wales, Warwickshire, Staffordshire, Lancashire, Yorkshire, Durham, and many other counties; and the whole carboniferous series rests upon an immense mass of *slaty rocks*, which forms the greater part of Cornwall and Devonshire, of north and south Wales, and portions of Lancashire, Westmorland, and Cumberland, and occupies large tracts in Scotland, especially in the border-counties, and the Highlands.

Granite, *syenite*, *greenstone*, and other pyrogenous rocks, are often seen protruding through these slaty rocks, forming extensive mountainous tracts, as in some parts of Cornwall, in the district called Dartmoor in Devonshire, in many parts of Wales, and the northern counties, and still more abundantly in the Highlands of Scotland, apparently forming the foundation of our whole geological series. Pyrogenous rocks of more recent origin, or *trap-rocks*, as they are often termed, are also seen piercing through, or traversing in dykes, many of the secondary strata, as near Dudley, in Staffordshire, and in the great coal-districts of Northumberland and Durham. Rocks of this kind occur also in masses of vast extent in many parts of Scotland, and on the north coast of Ireland.

The mineral structure of Scotland and Ireland does not present so much variety as that of England, primary rocks extending over the greater part of the former country, while the secondary strata occupy but a small area, and the tertiary do not perhaps exist at all. The principal secondary tract in Scotland (chiefly coal) extends from the Frith of Clyde to the Frith of Forth, and the northern borders of this country are partially fringed by secondary and trap-rocks. In Ireland, secondary rocks prevail chiefly in the Leinster district east and south-east of Dublin, and also in Antrim on the north-east coast, where they are overlaid by trap formations.

The small index-map which accompanies this volume will afford a good illustration of the general geological features of the British islands, while for more detailed information the reader is referred to the geological maps of Smith and Greenough, or the still more recent and correct one published by Messrs. Walker, in which both the subdivisions of the strata, and the position of the mineral and metalliferous districts, are accurately delineated from the latest and best authorities, and a great extent of original information embodied with that attainable from other sources.

GENERAL DESCRIPTION OF THE MOST IMPORTANT ROCKS, ESPECIALLY THOSE OCCURRING IN GREAT BRITAIN.

STRATIFIED ROCKS.

GENERAL REVIEW.—In the first part of this volume a general view was given of the constitution of the globe, and of the nature and relations of the materials of which it is composed. In the second the elementary facts and principles of geology have been explained, and a general review given both of the internal structure of the earth's crust, the nature and origin of those mineral masses of which it is constructed, and the changes which are now taking place upon its surface. The present portion will, therefore, be devoted to what may be termed *descriptive geology*, or a detailed account of those mineral masses before noticed only in general terms.

NATURE AND ARRANGEMENT OF FACTS.—It is by no means an easy task to bring within a small and convenient compass the prodigious mass of recorded facts relative to individual rocks which have resulted from the united labours of geologists. To the practical geologist, however, these facts form the most important branch of the science; they are intimately connected with the operations of the miner and engineer, and on various occasions enormous sums have been unprofitably squandered on useless and abortive undertakings, for want of a due acquaintance with them.

In the present descriptive notice of rocks but brief allusion will be made either to theoretical views regarding their formation, or to the lengthened catalogue of organic remains which has resulted from the labours of naturalists and geologists. These are subjects which occupy a large portion of all existing treatises on geology, in many of which they are most ably treated; but, the object of the present work being essentially practical, the most prominent and important points only will be noticed, the selection of facts being such as the author is convinced from observation and experience will be found of the greatest utility.

Arrangements of the stratified rocks have been drawn up by many geological writers with various degrees of success, those of earlier date being now mostly obsolete from the more advanced state of the science. The arrangements of Mr. De la Beche and of Professor Phillips are the most recent and valuable classifications of the kind: in the following description, the latter will chiefly be followed, as particularly applicable to the series of the British strata, and of foreign localities: further than to point out either the limited or general occurrence of the rock, but little notice can be taken.

In a detailed view of rock-formations, embracing so large a number of observed facts as is essential to its utility, much must depend on the mode in which these facts are arranged, and the particulars they are made to embrace: the following plan may be recommended, as including all essential information in a clear and convenient form, although too much in detail to be entirely followed in the present volume:—

1. Mineral character of the formation—its subdivisions, and thickness.
2. Its extent—physical geography, and foreign localities.
3. Mode of formation—characteristic fossils, and mineral contents.
4. Inclination and disturbance of strata—rise of springs, mineral and metalliferous productions, and their uses.

In addition to these general heads, characteristic sections, notices of favourable localities for observation, and other additional information, are occasionally desirable.

DILUVIAL DEPOSITS.

GENERAL VIEWS.—The general character of alluvial formations having been already noticed in treating of existing changes of the earth's surface, we may proceed at once to those termed diluvial, considering them chiefly with reference to our own country.

Diluvial deposits are those accumulations of sedimentary matter and water-moved fragments of rocks, *not due to existing causes*, which form a superficial covering over a large portion of the earth's surface, resting upon and concealing the great internal mass both of stratified and unstratified rocks, and entirely derived from the breaking up and partial destruction of them. Deposits of this kind are therefore the results of the last great catastrophes, which the surface of the earth has undergone, and at a period subsequent to its being inhabited by land-animals either similar or very nearly similar to those which we now see around us, as their bones are very frequently found enclosed in the mass.

EXAMPLES.—Diluvial beds are of almost universal occurrence, not only in our own but in every other country. We have familiar examples of them in the gravel-beds seen in the neighbourhood of London, in the vast accumulation of gravel spread over the lias in the midland counties of England, more especially from Shipston-on-Stour to the neighbourhood of Leicester (a distance of forty miles), in the scattered fragments of the Lickey quartz-rock in Worcestershire, which have been drifted in vast abundance from their original site through the valleys of the Evenlode and the Thames, to the vicinity of London, in the fragments and boulders of granite derived from Shap Fells in Cumberland, and drifted eastward into the counties of Durham and York. These transported fragments of rock differ in size, from that of an ordinary pebble to masses of several cubic feet or yards in content, and often many tons in weight. Their original derivation admits of being ascertained with the greatest precision, both from mineralogical composition, and from being actually traceable to the spot whence they were torn, on approaching which the boulders become more numerous, of larger size, and less perfectly rounded by attrition. The general direction which they have taken in this country appears to have been east or south-east, though not without exceptions, and in Scotland the surface of the rocks has in some places been found *grooved* or *scratched* in the above directions, as if from the passage of these blocks over them. It has also been stated, on high geological authority, that, "between the Thames and the Tweed, pebbles, and even blocks of rock, are discovered of such a mineralogical character, that they are considered as derived from Norway, where similar rocks are known to exist." On the general distribution of diluvial deposits it may be remarked that they are most abundant in valleys and plains, that they are often accumulated in those situations where the escarpment of hills has been opposed to their progress, but in many cases large boulders and transported fragments are found on the contrary on the summits of hills and other elevated situations. Examples of this may be seen in the high ground covered by Bagley Wood in Oxfordshire, on the hills near Bath, and many of the hills in Derbyshire.

The phenomenon now under consideration prevails on a still more extensive scale on the continent of Europe, where the boulders are often of enormous size, and the general direction which they have taken appears as in this country to have been southwards. Large blocks of granite, derived from the mountains of Norway and Sweden, are strewn over the level country which prevails in the northern states of Prussia, and are stated to extend into the Russian territory. In Switzerland masses of rock, derived from the summits of the Alps, are scattered on the opposite chain of the Jura mountains.

THEORETICAL VIEWS.—The precise circumstances under which the mass of sedimentary matter and boulders of rock termed *diluvium* were accumulated, and thrown into their present position, is a problem of great difficulty and intricacy, nor are geologists by any means agreed as to its solution. Without therefore entering into a discussion upon uncertain points, which the further progress of the science can alone clear up, it may be observed that the agency of powerful currents of water is undoubted, that the agency of icebergs in removing some of the largest and farthest transported blocks is at least probable, and that the animals living at the period in question (whose bones are often preserved in the mass) present a close resemblance to the present inhabitants of the globe. Among these may be enumerated the mammoth or fossil elephant (*elephas primigenius*), the mastodon, the hippopotamus, the rhinoceros, the Irish elk (*cervus giganteus*), the megalonyx, the megatherium, the hyena, the bear, and the horse.

FOSSIL REMAINS.—The bones of animals often found in caverns, as before noticed, both in this and other countries, belong to the classes above named, with the addition of the tiger, wolf, fox, the ox, and other existing animals, and the destruction of both may have been contemporaneous, or nearly so. The celebrated Kirkdale Cavern and its osseous relics were most ably explored and described by Dr. Buckland. Kent's Hole at Torquay is another example of the same kind, and many similar ones might be named in Germany and other parts of the continent, while the researches of Major Mitchell have made us acquainted with the occurrence of similar phenomena in Australia. The bones thus found in caverns and fissures of rocks are usually imbedded in indurated mud or sediment, often containing enclosed pebbles, thus forming an *osseous breccia.*

TERTIARY DEPOSITS.

GENERAL VIEWS.—The mineral character, and even the fossils, of tertiary formations, differ greatly, but in a general point of view they may be characterised as *local* assemblages of strata, containing fossils of *existing species*, and filling up depressions of greater or less extent occurring in secondary rocks. Their general composition consists of *sands*, *clays*, *marls*, and earthy *limestones;* they occasionally present distinct alternations of *marine* and *fresh-water* deposits, and admit of a beautiful classification, as regards their age, according to the proportion of recent species contained in a fossil state, that proportion being in the most ancient tertiary deposits, extremely small, and in the most recent amounting even to nine-tenths of the whole. Proceeding on this principle, Mr. Lyell has arranged tertiary formations into three great classes, the *Eocene*, *Miocene*, and *Pliocene*, distinguished, as the name implies, by the proportion of existing species, which in the oldest, the Eocene, amounts to only 3 or 4 per cent of the whole number, in the Miocene increases to 20 per cent, while in the Pliocene it constitutes a large majority or from 50 to 90 per cent of the whole.*

PARTICULAR DESCRIPTION.—The most recent tertiary strata occurring in Great Britain are deposits of sand and gravel, which have been termed the *upper marine formation*, and subdivided into the *Suffolk crag* and the *Bagshot sand*, these subdivisions being named from their most remarkable localities.

CRAG.—The *Suffolk crag* is a thin deposit, consisting of strata of sand and pebbles, enclosing shells, many of them belonging to existing species, together with bones, and in its lower beds abundance of corals. The whole mass is much impregnated with iron, and in some places does not appear to exceed thirty feet in thickness, although in others wells have been sunk without penetrating through it. This deposit occurs chiefly upon our eastern coast, in Suffolk and Norfolk, where it extends from Harwich on the south to Cromer on the north, a distance of nearly 70 miles, and forms a flat and fertile district. The crag is referred to the older Pliocene period.

BAGSHOT SAND.—The *Bagshot sand* occupies an extensive, barren, and rather hilly tract, in the western part of Surrey, stretching also into some of the adjoining counties.

This formation is a mass of yellowish sand, exhibiting but little variation of character, and very rarely containing fossils. It is generally covered with coarse siliceous gravel to the depth of five or ten feet, and in this gravel many silicified fossils are found, chiefly varieties of the *echinus*, as the *cidaris* and *spatangus*, and bivalve shells, as *pectens*, &c. A few very imperfect shells are sometimes found near the surface of the sand itself: they are converted into a coarse ferruginous sandstone, and appear to be the proper fossils of the formation. In districts where the Bagshot sand prevails, a hard and durable sandstone is often obtained for building, though not in any great quantity. This sandstone is found in masses of various size, often many cubic feet; it generally lies between the gravel and the subjacent sand, but sometimes in the sand itself. It consists of quartzose particles, with but little apparent cement, and is soft when first dug out of the ground, but hardens on exposure to the air. These masses of sandstone resemble some of our coal-grits; they are slightly rounded by attrition; and both their origin, and that of the great formation of sand over which they are scattered, offers an interesting problem to the geologist. It belongs to the Eocene period, and must be in some places from one to two hundred feet thick. Deposits of a somewhat similar nature occur, forming part of the Hampstead and Highgate hills, a hilly tract near Esher in Surrey, and also part of the New Forest in Hampshire.

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* In the *older* Pliocene 50, and in the *newer* Pliocene 90 per cent.

ALTERNATING MARINE AND FRESH-WATER DEPOSITS.—*Alternating marine and fresh-water deposits* occur in this country only in the northern part of the Isle of Wight, and the adjoining coast of Hampshire, where they rest upon the London clay. They consist of an assemblage of marly strata, containing numerous shells, from the nature of which their origin has of course been ascertained. The phenomenon of alternating marine and fresh-water deposits is exhibited more distinctly and on a larger scale in the neighbourhood of Paris, where tertiary deposits occur very analogous to those under consideration, and finally resting, like those of this country, on the great secondary formation of the chalk. Through the labour of Cuvier and Brongniart this district has obtained a classic celebrity, having been the earliest tertiary formation which was properly explored. The Paris basin affords the coarse limestone called "*calcaire grossière*," of which Paris is built; and the extinct races of quadrupeds named *paleotherium*, *anoplotherium*, &c., were first discovered there, but traces of them have since been found in the Isle of Wight.

LONDON CLAY.—The *London clay* is an argillaceous deposit of great extent, well known from its forming the substratum of the metropolis, and spreading over several of the adjoining counties, as Middlesex, Essex, Surrey, part of Berkshire, &c. It consists of an enormous mass of brownish or bluish clay, containing at irregular intervals nodules of a coarse, impure limestone, termed *septaria*, and, perhaps, in some places regular beds of limestone. The London clay was well exhibited in the excavations for the London and Birmingham Railway at Primrose Hill, and other places, where good specimens of the characteristic [illegible] were to be obtained. They are mostly univalve shells, a species prevailing very generally in tertiary deposits, and among the most abundant may be noticed, *fusus*, *rostellaria*, *voluta*, and two or three species of *nautilus*. The remains of crocodiles and fishes have occasionally been found, and also a singular description of fossils generally considered to be *fruits* and *seed-vessels*, of which many are now referred to the class of *zoophytes*. They have chiefly been noticed in the cliffs which border the Isle of Sheppey. The thickness of this formation varies considerably; about London it does not appear to exceed two hundred feet, but in other places it is four hundred or five hundred feet, or even more. The districts formed by the London clay are generally flat, and, although not naturally very fertile, this stratum admits of successful cultivation, more especially where, as is often the case, a superficial diluvial covering prevails above it.

Plastic clay.—This formation constitutes the lowest portion of our tertiary series, immediately overlying the chalk, and forming a zone intermediate between the upper surface of that stratum and the London clay. Its extent and localities will therefore be best understood when we trace the range of the chalk formation. The plastic clay derives its name from beds of fine clay used for making pottery, and other purposes, which often occur in this formation: the principal part of the deposit consists, however, of beds of sand variously coloured, and occasionally of pebbles. It contains a great variety of fossil remains, mostly univalves, as *cerithia* and *turritella*, sometimes bivalves, especially *ostrea*, which are fo abundantly in some of the strata near Woolw and Lewisham, and also at Reading in Berksh The plastic clay, occasionally, also, contains layer altered vegetable matter, somewhat resembling c a circumstance which, probably, gave rise to the er neous idea of the existence of coal on Blackhea about which and Shooter's Hill the plastic clay p vails, and where, in forming excavations, beds of t sort may have been discovered. The plastic c generally forms a flat country, and is estimated from one hundred to two hundred feet in thickne Both the plastic clay and the superincumbent L don clay, are referred to the *Eocene* period.

Although admitting of a natural and conveni separation, both the London and plastic clay may considered in a general point of view as forming great series of clayey and sandy deposits coveri that depression of the chalk in which the metrop is situated, and themselves occasionally overlaid beds of sand and diluvial accumulations, the wh assemblage forming the tertiary strata of this count of which a more limited deposit, as before notic occurs also in Hampshire and the Isle of Wig Tertiary deposits are very abundant on the Contin where they have latterly attracted much attenti more especially those of Italy and Sicily.

MINERALS OF TERTIARY STRATA.—The mine substances contained in our tertiary strata are little value or importance. *Iron pyrites* is the m abundant, and occurs in masses both in the Lond and plastic clay. *Selenite*, or *gypsum*, is also met with in these strata, and the occurrence of imperfect *coal*, or *lignite*, in the plastic clay has been already noticed. The masses of septaria have been much used for cements, and form the material of "Parker's cement," which is used for constructions under water.

RISE OF SPRINGS IN TERTIARY STRATA.—The mode in which water is supplied throughout the large area occupied by our tertiary strata is highly deserving of attention. The great mass of the London clay is itself impervious to water; the principal source of springs is, therefore, in the sandy and diluvial beds above it, or in the sandy beds of the plastic clay beneath it.

It thus happens that in London and its vicinity there are two kinds of wells, the deep and the shallow. The former penetrate completely through the London clay, often to a depth of several hundred feet, and furnish pure or *soft* water from the sands or chalk below; the latter, on the contrary, merely pass through the superficial sand and gravel, and derive their supply from the rain-water which, after filtering through these beds, is stopped by the tenacious clay beneath them. This water, being much impregnated with iron and earthy salts derived from the strata in contact with it, becomes what is termed *hard* water, that is a portion of its solvent power is lost in consequence.

It is to this peculiar geological structure, this alternation of pervious and impervious strata, and the arrangement of the whole into a vast trough or basin, that the rise of the water in the Artesian wells o London and its vicinity is owing, the water bein originally received by the loose pervious strata wher they crop out to the surface on the sides of the chal hills which surround the metropolis, and merely risin again to its own level, when pierced into by boring.

SECONDARY FORMATIONS.

General views.—The secondary formations of this country commence with the chalk, and extend over a large portion of England, more especially the central counties, from Dorsetshire on the south to Yorkshire on the north. The general characteristics of the secondary strata are the following:—they contain fossils of *extinct* species only, and with perhaps a solitary exception (the Stonesfield *Didelphis*), present no remains of land-quadrupeds, although lizards and crocodiles are abundant. They are mostly oceanic deposits, and are spread over very extensive areas, having arisen from causes far more general than those which produced the tertiary strata. We find in them very similar repetitions of sandy, clayey, and calcareous deposits to those of the tertiary series, but generally in a state of much greater induration, forming compact *sandstones*, *shales*, and *limestones;* and the unimportant lignites of the tertiary rocks expand in the lower part of the secondary formations into the thick and valuable beds of *coal* which characterise that portion of the series expressively termed the "*coal-measure*."

CHALK FORMATION.—Chalk, when pure, consists of lime combined with carbonic acid, in nearly equal proportions, but it often contains other substances in small quantity, as argillaceous and siliceous matter.

This formation is very extensively developed in England, and indeed throughout the whole of Europe, but it appears to be scarcely known in Asia, and not at all on the continent of America. The chalk, as must be well known, forms an extensive tract of country, spreading over a large portion of Wiltshire (where it forms Salisbury Plain) and of the adjoining counties of Hampshire and Dorsetshire. From this great central district the chalk diverges in four branches, strongly marking the physical geography of a large portion of England. The principal chain runs north-eastward, through Berkshire, Buckinghamshire, Hertfordshire, and Cambridgeshire, and from thence northward through Norfolk and Lincolnshire into Yorkshire, where it terminates at Flamborough Head. The second branch runs eastward through Surrey and Kent, terminating in the Dover cliffs. These two branches of the chalk are continuous below, but the intervening portion forms a vast hollow or depression, in which the tertiary deposits of the London basin, before noticed, are contained. The two remaining ranges of the chalk enclose the Isle of Wight basin in a similar depression, the northern branch running eastward from Winchester, through Hampshire and Sussex, to Beachy Head, the southern taking a south-easterly course through Dorsetshire to the coast, and re-appearing in the Isle of Wight, where the strata have been thrown by subsequent convulsions into a vertical position.

On tracing the course of the chalk, as above described, upon a map, it will be seen that the tertiary basins before noticed are both broken off eastward by the sea: it is proper to observe, however, that the remaining portions may be satisfactorily traced on the opposite coasts. The range extending from Flamborough Head to Dover may be traced for a great extent upon the Continent, while the two southern ranges terminate almost immediately on reaching the coast of France. It is also necessary to observe that, in the space intervening between the two chalk ranges terminating respectively at Dover and Beachy Head, the chalk is entirely broken off and discontinuous, this tract being occupied by rocks which will presently be described, and which here rise up in a vast ridge-shaped mass from *below* the exterior edges of the chalk. A deposit of chalk occurs on the north-east coast of Ireland, occupying part of the county of Antrim, which is remarkable for being overlaid by the mass of basalt which forms the Giants' Causeway and the neighbouring promontories. In Scotland this rock is unknown.

The chalk formation is divided into the *upper* and *lower* chalk, the former or upper portion being characterised by the occurrence of numerous regular beds of flint nodules, while the latter does not contain any, this lower part of the series being generally also more indurated and of a grayish colour. At the bottom of the chalk is a thick deposit of *marl*, generally called the *chalk-marl*, which separates it from the subjacent green-sand formation and occupies a thickness of from three to four hundred feet.

FOSSILS.—The chalk is unquestionably a marine deposit, and affords a great variety of organic remains. Among these may be noticed several species of *echini*, particularly the *spatangus* and the *ananchyte*, many species of shells, chiefly bivalves, as *ostrea*, *inocerami*, *plagiostoma*, *terebratulæ*, the teeth of sharks, and palates of fishes, &c. It is interesting to observe that, while the progress of geology has brought to our view many of the most gigantic forms of animal existence, and enabled us to contemplate the figures and habits of the extinct monsters of the ancient world separated from us, as they are both, by vast intervals of time, and by the most extraordinary revolutions of the globe, it has likewise made us acquainted with some of the minutest types of animal existence, which have singularly been preserved in a fossil state for our examination. Mr. Lonsdale, by an ingenious mode of investigation, has lately shown us the presence of millions of minute shells and coral lines embedded in the chalk, whose existence was not at all suspected; while the researches of Professor Ehrenberg of Berlin*

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* The following note from the anniversary address of the late distinguished president of the Geological Society, Mr. Lyell, will show the extraordinary minuteness of the fossil *infusoria* discovered by Professor Ehrenberg, which it may further be observed are possessed of an exceedingly complicated organization:—

" The flinty shells of which we are speaking, although hard, have opened a still more extraordinary field to our view, having shown that the stone called *tripoli*, much used for polishing, is wholly composed of the siliceous cases and skeletons of fossil animalcules. The Marquis of Northampton has lately discovered in the flints of Sussex and other places several species of a minute chambered shell, the *spirolinite*, which, although smaller than a pea, presents the same beautiful and complicated internal structure as the *nautilus*.

Springs, &c.—From its soft porous nature the chalk readily absorbs the rain which falls upon it, and, as this formation is very homogenous throughout and presents no retentive beds, this water passes without interruption through the upper part of the mass, till its passage is stopped below by the beds of marl and clay which underlie this formation. Hence, the lower beds of the chalk present copious springs, which either burst out naturally in the sides of the hills, or may easily be tapped by sinking wells. Chalk is seldom hard enough to be used as a building-stone; its most important use is for burning into lime, with which, from its extent, it supplies a large portion of England;

are very fragile, breaking like glass, and are therefore admirably adapted, when rubbed, for wearing down into a fine powder fit for polishing the surface of metals. It is difficult to convey an idea of their extreme minuteness, but I may state that Ehrenberg estimates that in the Bilin tripoli there are *forty-one thousand millions* of individuals of the *Gaillonella distans* in every cubic inch of stone. At every stroke, therefore, of the polishing-stone, we crush to pieces several thousands, if not myriads, of perfect fossils."

when pounded and washed to separate the sand it forms the substance called "whiting."

INCLINATION.—The general inclination of the chalk strata is very inconsiderable: the range extending from Wiltshire to Flamborough Head dips to the south-east, that extending from Wiltshire to Dover to the northward, the two ranges being, as before noticed, continuous below. The chalk range extending from Dorsetshire to Beachy Head dips southward, while that in the Isle of Wight, forming the opposite boundary of the same continuous mass, dips to the north. Although nearly horizontal in its natural position, the chalk has, however, in some places been thrown into high angles of inclination by subsequent internal convulsions. Such has been the case in the narrow range of chalk hills, expressively termed, from its peculiar form, the "Hog's back," which extends from Guildford to Farnham. The chalk has here been thrown into a highly-inclined position, and its abrupt outcrop at the surface gives rise to a long narrow ridge totally unlike the extensive undulating area which it occupies when in its usual nearly horizontal position. The mass of chalk extending from Dorsetshire to Beachy Head, which forms the northern boundary of the Isle of Wight basin, dips, as before noticed, to the southward; but the isolated portions of the southern boundary of this basin, which are visible on the coast of Dorsetshire, and running through the middle of the Isle of Wight, instead of having a regularly corresponding dip to the north, have, as before noticed, in some places been thrown into almost a vertical position, which is shared by the superincumbent beds of the London and plastic clay. It will thus be seen that two great lines of elevation have been experienced by the chalk in the south of England, both of which range nearly east and west, and that these have greatly disturbed its original horizontality of position, that in the Isle of Wight being subsequent to the deposition of the tertiary strata.

ORIGIN.—A sedimentary deposit which, like the chalk, contains innumerable remains of marine animals, must undoubtedly be considered of marine origin; but we have still to consider the question whence came the enormous mass of carbonate of lime which now constitutes the chalk formation? It is evidently not derivative from the older limestone rocks, for no fragments of them have ever been found imbedded in it. It has not been secreted from the ocean by vital agency, for, although the ordinary fossils are abundant, and an immense number of microscopic shells have recently been detected in it by Mr. Lonsdale, these form altogether a very inconsiderable portion of its whole mass. If we look to the manner in which lime is produced and deposited in the existing economy of nature, we shall, however, not only obtain a solution of the problem, but have a clearer insight into the origin of those enormous masses of calcareous rocks which, like the chalk, do not appear either to have been derived from the older limestones, or secreted from the ocean by vital agency. It is well ascertained that many springs issue from the earth, more especially in volcanic countries, highly charged with carbonic acid, and, therefore, under favourable circumstances, holding carbonate of lime in solution,* which they rapidly deposit, sometimes over large areas in the form of calcareous *tufa*, a substance which solidifies into a compact stone, as may be seen in the rock called Travertine near Rome. To similar depositions therefore, but on an infinitely larger scale, we may ascribe the origin of the chalk and many limestones. Lime, we know, must exist abundantly in the interior of the globe, since it forms an ingredient of granite and other igneous rocks; it may, therefore, be taken up by calcareous springs in their passage through these rocks, or they may derive it at once from deeply-seated original masses of this mineral.

We have still, however, to account for the nodules of flint which occur in such regular layers, a few feet separate, always in the upper part of the chalk in this country, and, on the Continent, sometimes in the lower beds also. Silica, as we see in volcanic countries, is occasionally held in solution by thermal waters, from which it is again deposited; as is beautifully exemplified in the Geysers, or hot fountains of Iceland, which speedily encrust leaves, branches, or other substances, which happen to be exposed to their action. Now, we find that silica exists in small proportion throughout the whole mass of the chalk with which, in its original state, it was doubtless completely intermixed. On examining the internal structure of flints, we shall generally find that the siliceous matter has been aggregated around some organic nucleus, as a sponge, or *alcyonium*. Now, when substances of different kinds are held in solution at the same time, there is a natural tendency of similar particles to aggregate together, and this aggregation is always most striking when portions of extraneous matter are present, forming local centres, or nuclei of attraction—a fact which we see forcibly exemplified by a great variety of geological phenomena. In the case of the chalk, it is therefore evident that the growth of sponges and zoophytes upon the bed of the ocean presented such nuclei for the aggregation of the siliceous matter held in solution, and determined the greater portion of it into those horizontal layers of flint with which every person must be familiar—a small portion merely being still left in the chalk, entangled, as it were, in the mass, and sufficient to indicate its former general diffusion. The occurrence of nodular limestone-beds, so common in argillaceous deposits, as, for instance, the *septaria* of the London clay, has arisen from similar causes to those above described, the calcareous matter having generally aggregated around a shell, nautilus, or other accidental nucleus.

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* Carbonate of lime is soluble in water containing carbonic acid, but is precipitated from the solution when the acid escapes; hence arise the stalactites found in caverns, and the calcareous incrustations common in limestone countries.

It would be incompatible with the plan of the present work to trace thus minutely the circumstances under which every individual group of rocks has originated; the foregoing will, however, afford a fair sample of the reasoning employed by geologists on subjects of this kind; and applying, as it does, to a formation so widely extended, so conspicuous, and so well known, as the chalk, it will be readily understood by almost every reader.

MINERALS, &c.—The only mineral contained in the chalk is iron pyrites, which generally occurs in brownish spheroidal masses, presenting internally a fibrous radiated structure and yellow metallic appearance. The districts where this formation prevails are generally marked by hills of a peculiarly smooth and rounded outline, often open and unenclosed, presenting extensive downs for pasturage. The valleys are remarkable also from often being entirely dry, and having no stream running through them. The thickness of the chalk varies considerably, but may be estimated as averaging from five hundred to one thousand feet.

GREEN SAND.—This formation considerably resembles the subjacent *iron sand*, from which, in this country, it is separated by an argillaceous deposit, called the *Wealden formation*. It consists of beds of sand, and sometimes of sandstone, having a calcareous cement, and occasionally contains beds of limestone. Small plates of *mica*, and grains of the mineral termed *green earth*, occur in it; from the latter the name is derived, as, when abundant, it gives the soil a greenish colour, although the tint is more often brown.

The green-sand formation is subdivided into the upper green sand, or "firestone" (quarried near

Reigate for hearthstones), which crops out immediately below the chalk, the well-known stratum of bluish marl, provincially termed "gault," and the lower green sand, which locally contains beds of coarse limestone, or "ragstone."

This formation occurs in many counties in England, and may be described generally, as following the line of the chalk before described, and emerging from below its exterior edge. The zone thus formed by it does not exceed a few miles in width. The limestone-beds of this formation, known in Kent by the name of "*ragstone*," are used for paving and building. The sandstone-beds are sometimes compact enough for similar uses; and at Blackdown, in Devonshire, beds of the compact siliceous substance called *chert* occur in this formation, which are extensively worked for whetstones. Beds of *fuller's earth* are found in the green sand at Nutfield in Surrey; the occurrence of "firestone" was before noticed. It sometimes contains iron pyrites, hæmatitic iron, and other mineral substances.

The organic remains are chiefly of marine origin; they are very numerous, and often in a very beautiful state of preservation. They consist of *corals*, many species of *echini*, *pectens*, *terebratulæ*, &c. Fossil wood, in a silicified state, is also of frequent occurrence. The thickness of the green sand is estimated at from four to five hundred feet.

WEALDEN FORMATION.—The Wealden formation occurs principally in Kent and Sussex, where it extends from Petworth and Haslemere to the coast at

Hastings, rising from beneath the chalk, and separating the two great branches which terminate at Beachy Head and Dover. Thin traces of it have also, it is supposed, been recognised, cropping out from below the chalk, in some of the midland counties, but it evidently thins out very much to the northward. This formation appears only to be known in this country, and may therefore be regarded as a local, although extensive, deposit, intervening between the chalk and oolites—two formations which extend over a large area on the continent of Europe. Three subdivisions have been established: the weald clay, which forms the upper portion of the mass, and contains numerous fresh-water shells; the iron sand, or Hastings sand, which forms the central portion; and beds of clay and limestone, containing fresh-water shells, forming the base of the series, which, from their being best known in the quarries of the Isle of Purbeck, have received the name of "Purbeck beds."

The upper part of this formation is argillaceous; the middle, termed the *iron sand*, or *Hastings sand*, is, of course, arenaceous; the lower consists of clays and limestones. The upper argillaceous portion often contains calcareous matter, becoming then a bluish or grayish marl. It sometimes includes beds of an impure argillaceous limestone, containing numerous fossils, which have long been quarried at Petworth in Sussex. This stone has hence received the name of "*Petworth marble*," and was formerly much used for ornamental purposes, and may thus be seen in many of our ancient churches. It has, however, been long superseded by the more beautiful and compact varieties belonging to the older limestone formations, and is now but little used.

The *iron sand*, or *Hastings sand*, as it is also called, which forms the middle part of the Wealden formation, consists of beds of sand and soft sandstone, which are generally of a brown colour, owing to the quantity of oxide of iron which they contain. From this circumstance, and from strata of this class prevailing over parts of Sussex, and especially near Hastings, the above names have been derived. This formation occurs also in Bedfordshire, Buckinghamshire, and some adjoining counties; some of the strata are so highly ferruginous as formerly to have been worked for the iron they contain, in some parts of Sussex. Beds of fossil wood and carbonaceous matter considerably resembling coal occur in this formation; and this circumstance has occasioned some expensive but fruitless attempts to procure this mineral at Bexhill, likewise in Sussex. The beds of sandstone are sometimes compact enough to be quarried for paving and other purposes.

The *Purbeck strata*, which form the base of the Wealden formation, are best exhibited in the quarries of the Isle of Purbeck, where the limestone-beds have, for a long period, been extensively quarried. They consist of clays, marls, and shelly limestones; the latter have a compact texture, and were formerly much used for paving-stones.

The Purbeck strata are separated from the adjacent oolites, in the Isle of Portland, by a very remarkable bed, locally known, by the quarrymen, as the "*dirt-bed.*" It is, in fact, a bed of vegetable mould, interposed between the fresh-water limestone of Purbeck and the subjacent marine limestone of the Isle of Portland. This bed is completely studded with the fossil trunks of trees, the roots imbedded in the soil, exactly as they grew at the period when this now-subterranean spot was clothed with what must have been a magnificent tropical forest; for it is ascertained that the trees belonged to those extinct species resembling the *Cycas* and *Zamia*, which could only have been the growth of a hot climate. These trunks are broken off at a few feet above the ground, and are completely silicified, or converted into a substance nearly resembling flint. The branches and upper portions torn off among the ancient revolutions of the globe—of which this remarkable spot affords so striking an example—have perhaps contributed to form the beds of lignite which occur in the superincumbent Wealden formation.

The organic remains of this formation differ greatly from those of the marine deposits above it, evidently pointing to a lake or æstuary origin, with the adjoining shores covered with vegetation, from which, as above noticed, the carbonaceous strata have probably been derived. The vast and extraordinary reptile, called the *Iguanodon,* which must have been upwards of 70 feet in length, was discovered by Dr. Mantell in this formation. It contains many æstuary and fresh-water shells, as *cyprides*, *unios*, &c.

The clayey portion of the Wealden rocks forms a flat tract of country; the sandy forms hills of considerable height, especially in the wealds of Kent and Sussex, where this formation chiefly prevails. The thickness of the formation may be estimated at about eight hundred feet.

OOLITE FORMATION.—The deposits classed together under this name are of a very complicated character, consisting of numerous alternating beds, following each other in nearly the same order, but differing considerably in composition and appearance. The predominant feature of the formation consists, however, in the frequent occurrence of a *limestone*, formed by small spheroidal particles, and held together by a cement, chiefly composed of calcareous, but frequently containing also argillaceous, matter. This limestone is found resting upon beds of calcareous sand and sandstone, which themselves repose upon a thick deposit of clay; and this triple association of strata, three times repeated, constitutes the oolite formation in this country. The oolites are very fully developed in England, where they form one of the most prominent and interesting features of our stratification. They extend from the coast of Dorsetshire on the south to that of Yorkshire on the north, averaging about two thousand feet in thickness, and from twenty to thirty or forty miles in breadth. The oolite formation occurs also in the Alps, in Germany, Russia, and other countries of Europe. Humboldt supposed he recognised it in equatorial America.

The limestone-beds in this country generally form a range of hills of considerable elevation, in the lower portion of which the sandy strata appear, while the clayey deposits, emerging from below, constitute a broad open valley, which intervenes between each of the oolitic ranges. The basset of the oolites forms, therefore, a series of wedge-like escarpments, the abrupt slope of which generally faces the north-west, forming a prominent feature in the physical geography of many of the midland counties. The soil formed by these strata is of course variable, but generally admits of being well cultivated.

The oolite series is very important as regards its architectural uses, the stone furnished by it being in many cases sufficiently durable for most purposes, and also easily worked, whence the name "freestone." The *Portland stone*, the *Bath stone*, and other kinds much valued by architects, belong to this formation; and it has furnished the materials for some of the finest structures in this kingdom, among which may be named St. Paul's Cathedral, the Monument of London, Westminster and Blackfriars' Bridges, &c.

Some of the oolitic strata, however, are too soft to resist the action of the weather, and in time suffer greatly from this cause, as may unfortunately be seen in many of the fine colleges and halls at Oxford, in which the more delicate and ornamental parts of the exterior are fast going to decay. For public buildings where great durability is an object, the oolites should always be used with much caution.

It will readily be seen, from the foregoing description, that the oolite formation admits of a natural and convenient subdivision into three portions, which have been named, from their relative situation, the *upper*, *middle*, and *lower* oolite. These subdivisions will next require notice.

UPPER OOLITE.—The prevailing feature of this formation consists of a whitish or yellowish oolitic freestone, which is perhaps best known in the Isle of Portland, where it has been extensively quarried for centuries under the name of "*Portland stone*." This limestone forms the upper part of the series, and the strata are not unfrequently separated by thin layers of the siliceous substance called "*chert*." Below the limestone a series of calcareo-siliceous beds are of common occurrence, and an extensive deposit of clayey beds, generally termed the "*Kimmeridge clay*," forms the lowest part of the formation. This last deposit is remarkable for sometimes containing strata of bituminous shale, which is so inflammable as to have been locally used for fuel, although forming a very indifferent substitute for coal. It has chiefly been applied to this use at a place called Kimmeridge on the coast of Dorsetshire, whence the name of "Kimmeridge clay" has been applied to the argillaceous deposit containing it. The occurrence of this substance has in many places led to fruitless trials to obtain that valuable mineral coal, which, as will be seen, is separated by an immense thickness of rock from the strata we are now considering, should it indeed exist below them. The upper oolite is considered to be about 400 feet thick.

MIDDLE OOLITE.—This formation resembles the one last described in many of its general characters, but is distinguished by the occurrence, in many places, especially in Oxfordshire, of an immense mass of coralline limestone, which presents such close analogies to the coral reefs now forming in tropical seas, that it can only be regarded as having had a similar origin. The upper part of the formation consists of a coarse oolitic limestone, with fragments of shells; the "*coral rag*" (or coralline limestone) is situated below this, being itself succeeded by calcareous and sandy beds, the whole resting upon the argillaceous deposit called the "*Oxford clay*." This formation much resembles the Kimmeridge clay; it contains beds of bituminous shale, and occasionally of coarse limestone. The flat country forming the valley of the Isis at Oxford consists principally of this clay, and from this locality its name has been derived. The middle oolite is between four and five hundred feet in thickness.

LOWER OOLITE.—This formation is generally subdivided into great oolite, lower oolite, and subjacent sandy beds, the whole resting upon the great argillaceous deposit called the *lias*. The mineral character of the great and lower oolite is nearly similar, both consisting of whitish, yellowish, or greyish oolitic freestone, but the former affords the best material for architectural purposes, the lower oolite being often of a very sandy texture. The two formations are separated by a series of argillaceous strata, one of which is the "*Stonesfield slate*," well known from the singular nature of its organic remains, which include several remarkable species both of marine and terrestrial animals, including the *Didelphis*, the only quadruped known in the secondary strata. The lower oolite, as before noticed, is often of a sandy nature, especially in Northamptonshire and some of the midland counties, and in the lower part of the formation the sandy beds often constitute the entire mass, separating the oolitic beds from the next formation or *lias*. The lower oolite is considered to average 400 feet in thickness.

LIAS.—The rock termed lias is a vast argillaceous deposit, forming the basis both of the lower oolite and of the whole oolitic system, its characteristic feature being the occurrence of a bluish clay or *shale*, containing thin beds of impure limestone. The lias is generally subdivided into *upper lias shale*, *marlstone*, and *lower lias shale*. The former generally appears as a tenacious deep blue clay, the marlstone consists of gritty and coarse calcareous beds, while the lower lias shale, which forms the principal part of the formation, consists of a dark-coloured slaty clay, or shale, sometimes bituminous. The limestone-beds chiefly occur in the lower lias shale; they seldom exceed a foot in thickness, and are disposed in parallel seams with a remarkable degree of regularity. The lias is seldom less than 500 feet in thickness, and in some situations it is perhaps twice as much.

Like most other members of the oolitic series, the lias is remarkable for the number and variety of its fossils, which throw considerable light on the mode in which this formation was accumulated. It is evidently, like the rest of the oolitic strata, a marine deposit, and must have been produced by a slow and uninterrupted action, favourable both to the existence and preservation of animal life. From the immense number of marine shells, it would not appear that the sea was deep, while, from the remains of *Icthyosauri* and *Plesiosauri*, animals of amphibious habits, it may be supposed that a neighbouring shore was in existence, a supposition confirmed by the vegetable fossils and beds of lignite which are contained in this formation.

In an extensive series of observations on the lias, and the subjacent new red sandstone, the author has been repeatedly struck with the great contrast which prevails between them; the former absolutely teems with animal life; not a quarry can be examined which does not present it under a great variety of forms. With the lowest stratum of the lias this abundance ceases; the new red sandstone, which comes immediately below it, contains scarcely a vestige of animal or vegetable existence, and the geologist may travel for miles, and examine quarry after quarry, without discovering a single trace of either. The probable causes of this remarkable contrast will be noticed in treating of the latter formation.

The general extent of the oolite formation from the coast of Dorsetshire to that of Yorkshire was befor noticed, and, in thus crossing the country, the rocks of this series form portions of the following counties: Dorsetshire, Somersetshire, Wiltshire, Gloucestershire, Oxfordshire, Northamptonshire, Rutlandshire, Lincolnshire, and Yorkshire, where they constitute a large portion of the East and of the North Ridings, finally terminating on the coast in the vicinity of Scarborough and Whitby, where fine sections are presented by the cliffs. The aggregate thickness of the oolite formation has already been stated at about two thousand feet; but it should be observed that in the southern counties the beds become much thinner. At Pucklechurch in Gloucestershire, and other places, they have been sunk through to reach the coal beneath, and found less than two hundred feet in thickness.

The oolite series occurs very sparingly in Scotland: on the western coast it appears in the Isle of Mull and the Isle of Sky, and skirts a portion of the eastern coast from Brora to Caithness; at the former place it contains workable seams of lignite, or imperfect coal.

Fossils.—The organic remains of the oolite formation are extremely numerous and highly interesting. Many of the species are of marine origin, while others are littoral, showing that these deposits were formed in a sea bounded by shallow creeks and æstuaries. The forms are also such as to prove that a humid and tropical climate existed at the time.

The occurrence of *corals* in the middle division of the oolites has already been noticed. *Ammonites* (especially A. *Bucklandi*, and A. *Conybeari*, are found in great abundance in most of the oolite strata: this series has indeed been termed "*Ammonean rocks*," from this circumstance, by a continental writer. *Gryphites* (especially G. *incurva* and G. *dilatata*) and *belemnites* are also found in great number. Among the bivalve shells, which are very numerous, *trigonia* and *ostrea*, (especially O. *deltoidea*,) *teretratula*, *cardium*, and *plagiostoma*, are very common in some of the oolitic strata.

The most remarkable fossils of the oolites are, however, the remains of saurians and crocodiles of immense size, and of extinct species. Among these the *icthyosaurus*, the *plesiosaurus*, and the *megalosaurus* are most common and best known, both from the fine skeletons placed in our museums, and the various plates and figures of them which have been given in various geological works. Saurian remains, although found in the middle and lower oolite, are most abundant in the lias.

It is necessary to observe that, notwithstanding the general character which pervades the organic remains of the oolites, considered as a whole, each of the three great subdivisions is also distinguished by its own peculiar fossils, and even many individual strata are strongly characterised in the same manner.

MINERALS.—The mineral contents of the oolites, like those of the rocks above them, are not very important; they consist in the occasional occurrence of beds of lignite in the lower oolite, and of layers of ironstone and pyrites in the lias. The lignite is worked to a small extent for fuel in the eastern moorlands of Yorkshire, but the quality is indifferent; the lias shale is worked for alum, on the coast near Whitby, and produces a large quantity of this substance, which arises from the decomposition of the pyrites, and the union of the sulphuric acid with argillaceous matter.

Before quitting the oolites, it is proper to observe that, of the numerous unsuccessful attempts to obtain coal which have been made in various parts of England, by far the greater number have been in rocks belonging to this formation. This circumstance has been occasioned by several causes, which it may be well here to notice.

Many of the clayey beds of the oolites, and more especially the dark-coloured shale of the lias, considerably resemble the clays and shales belonging to the coal formation, thus countenancing the idea of the existence of coal, as it is usually found to accompany strata of this description. The occurrence of bituminous shale and of lignite, both combustible substances, and bearing, to the common observer, some appearance of imperfect coal, has already been noticed; and, reasoning on these delusive analogies, that true coal would be found on sinking to a greater depth, large sums have at different times been expended in absurd and unsuccessful trials, encouraged either by ignorance or fraud.

This waste of capital might in most cases have been avoided by a general examination of the district, which should always precede mining operations, and which would at once have dissipated any illusion arising from partial and deceptive appearances. At the present time, indeed, the stratification of this country is laid down with so much accuracy on our geological maps, that a glance at one is sufficient to show any one tolerably versed in geology where there is any probability of obtaining coal, and where there is not.*

But few springs rise from the lias or, indeed, any of the argillaceous strata of the oolites, and these are often impregnated with mineral matter, especially in the lias, as at Bath and Cheltenham. The supply of water is chiefly obtained, therefore, from the sandy and calcareous beds, or from superficial sandy and gravelly deposits resting upon the clayey strata.

NEW RED SANDSTONE.—This rock, with its associated red marl, prevails over a large portion of central England, and presents a remarkable uniformity of character throughout; the districts formed by it may easily be known, even to the most unpractised eye, from the redness of the soil, and the deep red tint of the substrata, whenever exposed to view by any excavation.

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* The necessity of combining scientific knowledge with practical, in conducting mining operations, must be sufficiently apparent to all who are competent to form an opinion on the subject. A curious instance of the manner in which merely practical men may be misled by deceptive appearances occurred to the author some years since. He was making an examination of the lias preparatory to some excavations in Worcestershire, accompanied by two very intelligent working miners from Staffordshire, and bestowed some attention on a spot where, many years before, an unsuccessful and, indeed, absurd trial, had been made to a great depth for coal. The rubbish lying about the pit plainly showed that the whole excavation had been carried through the lias, but, on asking the opinion of his companions, they both declared the spot a very promising one for coal, and would not believe but what it either had been or might be found there. We may thus perceive the causes which have occasioned vast sums to be thrown away at various times upon similar fruitless undertakings, some of which are even now being carried on in spite of former failures.

In this formation four subdivisions may generally be recognised. The upper portion of the mass usually consists of a reddish clay or marl, below which is a soft micaceous sandstone, frequently of a deep red colour, but occasionally of a whitish or yellowish tint. The sandstone is underlaid by thin calcareous beds of a conglomerate nature, the whole generally reposing on a coarse siliceous conglomerate, composed of the fragments of older rocks.

This formation constitutes in England a large and important tract of country. It appears in Devonshire and Somersetshire, extending over a large portion of the former county in the neighbourhood of Exeter and Taunton. Near Gloucester it is again seen emerging from below the lias, and it thus follows the line of this formation to the northward, as far as the mouth of the Tees. It occupies a small portion of Gloucestershire, the greater part of Worcestershire, and the adjoining counties, Warwickshire, Staffordshire, and Leicestershire. From thence it extends northward through Shropshire and Cheshire into Lancashire, where fine sections of it are laid open in the deep cuttings on the Liverpool and Manchester railway. The eastern branch of the new red sandstone forms a large tract in Nottinghamshire and in the East Riding of Yorkshire, and extends through Durham to the coast. The new red sandstone, with its subjacent formations, exists in several parts of

Scotland, chiefly skirting the eastern coast in the vicinity of the Firth of Tay and the Murray Firth, and in the county of Caithness. This rock is found in almost every country in Europe; it occurs also in Russia, and abundantly in equatorial America.

Rock-salt, &c.—The districts formed by this deposit are usually flat, or only moderately hilly, and in this country are distinguished for their richness and fertility, constituting some of the finest land in England. Its metallic produce is unimportant, but it is remarkable for containing, both in this and other countries, immense deposits of *rock-salt*, which forms, therefore, its most characteristic feature. Gypsum also occurs abundantly in this formation, associated with the rock-salt, both these substances being found in the upper portion of it or the red marl. The salt deposits of this country are situated in Cheshire and in Worcestershire. In the former county vast quantities are obtained by mining, immense excavations being formed in the beds of rock-salt. In Worcestershire the salt is entirely made by evaporating the brine resulting from springs of water flowing over the beds of salt, and thus becoming strongly impregnated with this substance. The same method is also practised in Cheshire to a very considerable extent. The quantity of salt made in this country is so great, that after supplying the demand for home consumption, no less than 400,000 tons are exported annually from Liverpool. The rocky strata of this formation are not generally compact enough to form a good building-stone, nor is the tint a pleasing one for this purpose.

Chester cathedral is built of this sandstone, and affords an example of its soft crumbling nature, the original sharpness and elegance of the ornamental parts having entirely yielded to the long-continued action of the weather.

LOCAL DETAILS.—The general nature of the new red sandstone will be best understood from the following notice of its characters, extracted from a detailed account of the rock-salt district of Worcestershire, by the author.

Throughout a considerable portion of Worcestershire, the prevailing stratum is the *red marl*, which forms the upper portion of the red sandstone series, and is here very extensively developed, being several hundred feet in thickness, and furnishing good sections in the neighbourhood of Worcester and many other places. The next lower member of the series is a pale argillaceous sandstone, of which good sections are afforded about Bromsgrove, and at the neighbouring village of Finstal. Below this we find a deep red-coloured sandstone, constituting the most characteristic part of the formation, and well exhibited on the flanks of the Lickey range, and in the western part of the county. Thin irregular calcareous beds occur in the lower part of this sandstone, which are also seen around the Lickey, and the base of the whole series is formed by conglomerate beds, which are most distinctly seen in the western part of the county, near the junction of the red sandstone with the older subjacent rocks. The tract thus constituted is gently undulated with hill and dale throughout, presenting generally a rich and fertile district, with little external indication of containing mineral wealth below.

In the mineral composition or structure of the rocks above noticed as constituting in Worcestershire the new red sandstone formation, there is little which requires remark—and of organic remains they are almost entirely destitute. The red marl is usually of a dull red colour, and of a hard and slaty, or rather, perhaps, lamellar texture, when first exposed to the atmosphere, although it afterwards disintegrates and crumbles away. It generally contains sufficient calcareous matter to effervesce briskly with acids. Seams of hard whitish or greenish marl very generally occur in it, and veins of gypsum are abundant in depth, though I have never seen them in any excavations near the surface. It is in this lower part of the formation exclusively that the beds of rock-salt, varying much, however, in purity, are situated; they are five in number, being respectively 6 inches, 10 feet, 6½ feet, 39 feet, and 30 feet in thickness, besides which, a large quantity of salt is intermixed with the intermediate beds of marl*. The pale-coloured argillaceous sandstone before noticed as underlying the red marl is generally soft, micaceous, and very distinctly stratified; it is quarried to some e tent for building, making troughs, &c. In some of the upper beds I have noticed a few coaly remains of vegetable substance, but no shells or marine exuviæ. The deep red sandstone is composed of quartzose grains, strongly tinted by the per-oxide of iron, and not very firmly cemented together, the mass being too incoherent to be applied to any useful purpose. The calcareous beds are very impure, and

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* The brine obtained at Droitwich is perfectly clear and transparent, like ordinary water; nor is there any appearance in it which would indicate to the casual observer its strong impregnation with mineral substance. It usually contains, however, from twenty-five to twenty-six per cent. of salt, and, therefore, closely borders on the point of saturation, the specific gravity being thus raised to about 1,200. At Stoke Prior the impregnation with salt is not so complete, and the brine is consequently somewhat weaker. The large supply required

for evaporation is at both places pumped up to the surface by steam-engines, although, if suffered to rise, it would at Droitwich overflow the surface.

The processes made use of in obtaining the salt from this brine are extremely simple, consisting chiefly of an extensive system of evaporation, performed in very large but shallow iron pans, under which suitable furnaces are placed. Several of these pans are usually arranged under one building, having openings in the roof, something like those of a gas retort-house, by means of which the steam or vapour escapes into the external air, where it is speedily condensed. These ranges of buildings, and the white clouds of steam issuing from them, give the town of Droitwich a somewhat peculiar appearance on approaching it from either of the low ranges of hills by which it is surrounded.

The salt-pans vary in size, but the most usual dimension are twenty-three feet long, by eighteen feet wide, and one foo in depth; some few, however, are very much larger, being 12 feet long, and eighteen feet wide. Each pan, of the ordinar size, is heated by three fires below it, with flues to conduct th heat; these pans require about two tons of coal per da (twenty-four hours) to maintain the proper temperature, an in that period are capable of producing from three and a hal to four tons of salt; the expenditure of coal requisite to pro duce a ton of salt being estimated at from ten to twelve cwt.

generally coloured by oxide of iron. The conglomerate beds are coarse, consisting of rolled fragments of the older neighbouring rocks, from which they have evidently been derived.

The general inclination of the new red sandstone is very trifling, and towards the south or south-east; but in the neighbourhood of the Lickey, and in other places, its original position has been much disturbed, the dip being considerable, and in very opposite directions.

It appears to me impossible to ascertain the thickness of the various members of the red sandstone formation in any other than a very rude and approximate manner. I should, however, be inclined to consider it nearly as follows:—

SUBDIVISIONS.	Thickness in Feet.
Red marl, the upper portion characterised by the occurrence of whitish and greyish seams, the lower by the presence of gypsum and rock salt, probably about 500 feet	500
Soft argillaceous sandstone, light coloured, and sometimes micaceous, about 200 feet . . .	200
Soft ferruginous sandstone, of a bright red colour, and commonly micaceous—perhaps 200 to 300 feet	250
Thin and irregular calcareous beds, very impure, and often of a reddish colour, apparently interstratified with the sandstone. Thickness trifling, perhaps about 50 feet	50
Lower conglomerate beds, thickness very uncertain, may be about 200 feet	200
Total	1200

The foregoing estimate, it will be seen, gives the thickness of the new red sandstone in Worcestershire at about twelve hundred feet; and great as this is, I do not consider that it can be stated much below. If we compare this immense development with its thinness in some parts of the adjoining counties of Gloucester and Somerset, where both it and the lias are sunk through, in order to reach the coal-measures, we are presented with a most remarkable phenomenon. Was this vast sedimentary deposit produced by the elevation of the older and trappean rocks which now border upon it to the westward—Did the set of ancient oceanic currents tend to carry the great mass of this deposit to the northward, leaving but thin traces of it to the south? These interesting queries can alone be solved by numerous and accurate local observations.

ORIGIN AND THICKNESS.—The new red sandstone is unquestionably a marine deposit, but is remarkable for containing scarcely any trace of organized bodies, perhaps owing to the turbulence of the sea in which it was deposited. Its general thickness is estimated at about eight or nine hundred feet, but in some of the southern counties is very inconsiderable.

MAGNESIAN LIMESTONE.—The distinguishing character of this rock, as its name implies, is derived from its containing *magnesia*, which is generally found in it in the proportion of about twenty per cent; in the north of England a deposit called the lower red sandstone intervenes between it and the coal. The magnesian limestone is of a compact and granular texture, and the colour usually whitish or yellowish; it forms an excellent building material, and is deserving of a more extensive use for this purpose. This rock does not occur very extensively in England. The principal mass of it extends from the town of Nottingham to the coast of Durham, skirting and partially overlying the coal-fields of Yorkshire and Durham, some of the collieries having been worked for a short distance under it. On the Continent this rock occurs in France, Switzerland, and Germany.

The organic remains are by no means numerous in this country. They consist of *corals*, *shells*, singular species of *fishes*, and in some localities the bones of *saurians*. The mineral contents are not very important, but the ores of lead and zinc have been found in sufficient quantity to admit of being worked in Somersetshire, and exist more sparingly in other places. The thickness appears to be generally about three hundred feet.

COAL FORMATION.—In the present outline of geology, the fullest notice possible will be given of this very important formation, which presents so many interesting features, whether in an economical or geological point of view, that a volume would be required for its complete description. The most general view which can be taken of it, is as an assemblage of numerous beds of *coal*, *shale*, *indurated clay* and *sandstone*, (the shale and clay often containing layers of *clay ironstone*,) irregularly alternating together, and in many cases resting on a thick deposit of sandstone, termed the "*millstone grit.*" This deposit itself rests on the *mountain* or *carboniferous limestone*, but is generally separated from it by beds of shale, called the *limestone shale*. The mountain limestone which thus forms the base of the carboniferous series, in some situations presents immense hollows or depressions in its upper surface, in which the rocks constituting the coal formation have been deposited, and consequently it often emerges from below, all around them. This occurs most remarkably in the coal district of South Wales, and in that of the Forest of Dean, in Gloucestershire, as will be seen on referring to a geological map of England. From being thus encircled by the mountain limestone, the terms often used of "coal field," and "coal basin," are no doubt derived.

FAULTS.—Although both the strata of coal, and those of rock in which they are enclosed, are thus continuous over very large areas, their regularity of position is very greatly disturbed by what the coal-miner terms "*faults*;" these being, in fact, immense *rents* or *cracks*, passing through the rocks to an unknown depth, and not only breaking them asunder, but causing the mass on one side to be greatly elevated, or on the other to be greatly depressed; so that considerable difference of level often exists between the same beds, on one side of it and on the other. These *faults* or disruptions may generally be referred to volcanic action, which, as before noticed, prevailed to a great extent during the formation of the stratified crust of the globe. They occur in many of the secondary strata, and are sometimes noticed even in tertiary deposits, but are most remarkable and best known in the coal-measures, from the great subterranean works which are carried on there. Both the relative position of the various rocks of the coal formation, and the nature of these dislocations, will be more clearly understood by reference to fig. 2, plate 2, which gives an imaginary section of a coal-field, the seams of coal being indicated by the strong black lines.

VARIETIES OF COAL.—Several varieties of coal have been described by mineralogists, but as regards our present purpose it will be sufficient to notice two. The first consists chiefly of *bitumen* and *carbon*, the second contains little or no bitumen, but is chiefly composed of carbonaceous and earthy matter.

The first class, called "black," or "foliated coal," is the kind commonly found in Staffordshire, Lancashire, and the great coal district of Northumberland and Durham, and is universally known from its affording almost the only fuel made use of in London and the adjoining counties. Being principally shipped from the vicinity of Newcastle, it is often called "Newcastle coal." This species of coal burns with considerable flame and smoke, and gives out a large quantity of gaseous matter, or *carburetted hydrogen**, in a very impure state. Even in its natural situation in the mine, this gas is given out by bituminous coal, owing to a natural and spontaneous distillation which is at all times going on. It is thus accumulated in the fissures of the rock and excavations of the mine, and when mixed in certain proportions with atmospheric air*, forms the dreadful "*fire damp*," so well known from its frequent explosions and desolating effects.

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* Procured by distillation, and purified by subsequent processes, this is the gas with which our streets are lighted.

The second class of coal is most abundantly found in Wales and Ireland, and is named from its principal localities, "Welsh coal," and "Kilkenny coal." Varieties of it are also known by the names of *glance coal*, *anthracite*, *stone coal*, and *blind coal*. This species of coal, unlike the former, burns almost without flame, and with very little smoke; it also gives out a much smaller quantity of gaseous matter during combustion.

These two species of coal may be considered as peculiar to the coal formation, and are in this country the only ones of any great importance in an economical point of view, although coal, or substances bearing some analogy to it, are, as before noticed, found in several other formations.

MINERAL STRUCTURE OF THE COAL FORMATION.—The beds of coal found in particular coal-fields are sometimes very numerous, amounting to thirty or forty, or even twice that number, but many of them are of such inconsiderable thickness as not to be worth working. They may be said generally to vary in this respect from a few inches to several feet, not usually, however, exceeding six or seven, and from beds of the latter thickness by far the greatest quantity of coal is obtained, especially in the great coal districts of Northumberland and Durham. In Staffordshire, however, a very fine seam (or rather assemblage of seams) of coal occurs, which is not less than thirty feet in thickness, and is thence called the "ten yard coal." It must be observed that the same seam of coal varies much both in thickness and quality, in different parts of the area over which it is known to extend, and sometimes *thins out*, or disappears altogether.

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* The proportions of carburetted hydrogen and atmospheric air which form explosive mixtures, vary from one-fourth to one-twelfth of the former. The greatest danger exists, however, when the carburetted hydrogen is in the proportion of about one-eighth or one-ninth.

The beds of shale interstratified with the coal are equally numerous, but commonly of much greater thickness. This rock considerably resembles the shale of the lias, but is generally more compact. It is an indurated clay of a slaty texture, and commonly of a bluish or blackish colour; large heaps of it may generally be seen around the mouth of every coal pit. This substance is important from often containing our great deposits of iron, the ore of this metal being found abundantly in shale and clay, both in regular layers and in the form of detached nodules. This ore, "*clay ironstone*," as it is called, is a brownish earthy-looking substance, and contains about thirty per cent. of iron, combined with carbonic acid and much earthy matter.

The beds of indurated clay, often many feet in thickness, which occur in the coal formation, are chiefly valuable for affording the material called "fire-clay," which is used for the manufacture of fire-bricks for building furnaces, and is, therefore, a very valuable material in those districts where iron is made.

The beds of sandstone interstratified with the coal are very numerous, and generally several yards in thickness, being often separated by thin layers of shale. These sandstones are generally rather fine grained, of a uniform texture, and of a whitish or light brown colour. Some of them contain disseminated scales of mica, and are of thin slaty texture. They are used for building, paving, and various other purposes.

Coal districts are generally rather hilly; that of South Wales is very abrupt, and in some parts much elevated. The soil is commonly productive though not remarkable for fertility. Springs are thrown up by the sandstone strata, which are generally full of water, and occasion great trouble to the miner in sinking through them. It frequently happens both in this formation and those lying below it, that springs burst out to the surface along the line of faults, which being filled with clay dam up the water on one side. The general thickness of the coal formation may be estimated at from two to three thousand feet, but varies much in different localities, according as the series is more or less perfectly developed.

ITS DEVELOPMENT IN GREAT BRITAIN.—The coal formation is very extensively developed in this country, and forms one of the most interesting as well as most important features in the geology of England, our coal mines being the most important and extensive in the world. The position and extent of these important tracts to which England owes so much of her wealth and prosperity, can only be vaguely indicated by description, but will at once be clearly and distinctly recognised by reference to a geological map of the country. It is difficult to ascertain the annual produce of the various coal districts of Great Britain, yet we may probably estimate that at the present time it does not fall short of the enormous sum of thirty million tons, while our produce of iron, chiefly from the same series of rocks, must amount to between eight and nine hundred thousand tons. The immense importance of these internal sources of wealth can scarcely require comment.

FOREIGN LOCALITIES.—The coal formation is found in many parts of France, Spain, Belgium, Germany, and indeed most parts of the continent of Europe; it occurs also in Asia, where it has long been extensively worked by the Chinese. It is found in many parts of North and South America, and also in India and Australia.

ORGANIC REMAINS.—The organic remains of the coal formation consist of many shells of freshwater origin, and occasionally fishes. Land plants occur in great abundance and variety, belonging to extinct species bearing considerable analogy to those now growing only in tropical climates. These plants are mostly succulent and of enormous growth; they are chiefly found in the beds of shale, and are remarkable for the beauty and richness of their cortical markings, as well as the fine state of preservation in which they are found. They consist of *calamites*, *equisetaceæ*, *sigillaria*, *lepidodrendra*, species of *tree ferns*, &c., and are usually found in the state of casts in the shale beds, sometimes, however, compressed trunks are discovered, which have been converted into sandstone.

ORIGIN OF COAL.—It appears well ascertained that coal is a vegetable origin, many circumstances leading to this conclusion. Among these perhaps the most obvious are the gradual transition which may be traced between perfect coal and decided vegetable matter, the numerous remains of plants found imbedded in the coal strata, and the woodlike and fibrous appearance which has recently been found by microscopic inspection, to pervade every species of coal.

Reasoning from the general character of the coal formation and the natural operations now in progress, we may conceive the luxuriant vegetation of that remote period which must have surpassed even that of our present tropical climates, to have been swept away by successive torrents into lakes and æstuaries, and buried in succession beneath deposits of mud and sand, now consolidated into shale and sandstone, while the vegetable matter has been converted by pressure and other circumstances into coal. The enormous quantity of carbon fixed in a solid state by vegetable agency in our coal deposits, (usually 70 to 90 per cent. of the entire mass of coal,) has given rise to some very remarkable and interesting speculations, as to the constitution of the atmosphere at the carboniferous era, and there can be little doubt that it was then much more highly charged with carbonic acid gas than at present, a circumstance which while highly favourable, if not in fact essential, to the extraordinary vegetation of that period, must at the same time have been inconsistent with the existence of the higher orders of animal life. This idea is strongly confirmed by the fact that the higher forms of animal existence, which are totally unknown either in the coal strata or in any formation below it, are plentifully exhibited in the strata of subsequent deposition. The agitated sea in which the new red sandstone was deposited, was not of course favourable to organic preservation, but in the lias and oolites, depositions of a more tranquil period, it will be recollected that such remains are exceedingly abundant.

DETAILED VIEW OF THE BRITISH COAL-FIELDS.—After the above general views of the coal formation, we may next proceed to consider in detail the various important coal-fields which occur in Great Britain, beginning with the most southerly, and describing the principal features which characterise each with as much detail as our limits will allow.

SOMERSETSHIRE COAL FIELD.—The coal formation, as before noticed, forms one of the most interesting as well as most important features in the geology of this country. The most southern of our coal-fields are those of Somersetshire and Bristol,* and are remarkable from the inclined strata of the coal and subjacent rocks, being overlaid by horizontal deposits belonging to the new red sandstone and oolite formations, which are here much thinner than in the northern counties, and have been successively sunk through in order to reach the coal-measures.

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* These may more correctly be regarded as forming one great coal-field, but much obscured in its features both by undulations of the coal-strata and from being overlaid by more recent deposits. The above subdivision is, however, the most general view.

The Somersetshire coal-field is situated on the northern flanks of the Mendip hills, upon the carboniferous limestone of which it rests; the Bristol coal-field forms an extensive tract lying to the north or rather north-east of that town, and rests upon the carboniferous limestone which rises to the surface at Clifton, and forms the well-known scenery of the Avon. This limestone crops out from below the coal on the western and northern, and partially also on the eastern side. The carboniferous series is here very perfectly developed, exhibiting in a descending series, first the coal measures, then thin traces of the millstone grit, the great formation of carboniferous limestone, and finally (forming the axis of the Mendip hills) the old red sandstone. There are many faults, but the dislocations are on a less extensive scale than those of the north of England. Both these coal-fields are about twelve miles in length, but less than half that distance in breadth; they contain fifty or sixty seams of coal, most of which, however, are very thin, those chiefly worked, not exceeding three or four feet in thickness. The district has been extensively worked, and is beginning to exhibit symptoms of exhaustion. The mines are remarkable for their depth, which exceed that of any other collieries in Great

Britain,* and in some cases is more than twelve hundred feet.

FOREST OF DEAN COAL-FIELD.—The coal-field of the Forest of Dean occupies a tract about ten miles in length, from north-south, and five or six miles in width; the coal measures rest upon the carboniferous limestone, being in fact, deposited in a remarkable elliptical basin of that rock, which crops out nearly all round them. Rich beds and masses of iron ore occur in this district, which have given rise to the manufacture of this metal, which has long been carried on here, but not to any great extent, the number of furnaces being very small.

GREAT SOUTH WALES COAL-FIELD.—The extensive coal district of South Wales and Monmouthshire is one of immense area, and of great importance, both from its present enormous produce of coal and iron, and from the large portion of it which, being yet unwrought, may be considered in the nature of a reserve for future ages. The western termination of this basin is on the coast of St Bride's Bay, which bounds it in that direction, and probably spreads over a portion of it; the eastern boundary is near Pontypool, and the entire length extends therefore about ninety miles along the coast of Glamorgan, Caermarthen and Pembroke, but deeply indented by

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* Pemberton's coal-pit near Sunderland, which will be noticed in treating of the Durham and Northumberland coal-field, forms, however, an exception, being much deeper than the Somersetshire mines.

Caermarthen Bay. The breadth of the basin varies much, being greatest at the eastern extremity, where it is about twenty miles, but decreasing in the western extremity to about five or six. There is also a remarkable difference in the quality of the coal in the eastern and western portions of this coal-field; in the former it is bituminous, in the latter of the kind called by mineralogists anthracite, or more commonly known as "stone coal" or culm. The eastern part of this coal-field is divided into two distinct basins, by a great line of elevation running through it east and west, from near Aberafon, to a few miles north of Caerphilly.

The immense area above described, has been stated to contain no less than twenty-three workable seams of coal, varying in thickness from a foot and a half to nine feet, and forming an aggregate thickness of *ninety-five* feet. The beds of coal are interstratified with numerous beds of shale, and a considerable mass of gritstone of a schistose texture locally called "*Pennant*," intervenes between and separates the upper coal beds from the lower ones, the former being provincially termed the "rock veins," while the latter (perhaps from the regularity with which they are seen cropping out around the edges of the basin) are called the "line veins." Considerable workings are carried on both in the upper and lower beds, but most extensively perhaps in the former, the situation of which, in many localities, admit of the coal being raised at a comparatively small expense, without sinking to the deeper beds.

In addition to the importance which the South Wales coal-field derives from its great superficial extent, from its thick and numerous beds of workable coal, and from the ease of working, owing to the shallow depth at which they may be wrought, it is no less distinguished as the richest depositary of iron ore in this country. As in other coal districts the iron is in the form of clay ironstone, and occurs in nodular masses disposed in beds or strata, both in the shale-beds which lie beneath the coal, and interstratified with the beds of coal themselves. The ironstone is provincially termed "mine," and the average quality produces from thirty to thirty-five per cent of iron, although the actual produce of different samples varies from twenty to more than fifty per cent.

The vast mineral resources of the South Wales coal-field were, till the present century, very unduly appreciated; for some years past, however, great and rapid progress has been made in their development, and the annual produce of coal at the present time is, in all probability, but little inferior to that of the great coal-field of Northumberland and Durham, the most productive in the whole world. The quantity of coal produced by this district during the last year, (1837,) has been estimated by an intelligent correspondent of the "*Cambrian*," at little short of *four million* tons, of which about one half, or *two million* tons, were consumed in the iron works of Monmouth and Glamorgan.

The annual produce of iron is stated by the same authority as somewhat under 400,000 tons,* being the produce of about 100 blast furnaces, a quantity exceeding that produced by any other district in the world, although that of Staffordshire comes next to it.

From the mountainous nature of the country, and the cropping out of numerous beds of coal and ironstone in the deep valleys which intersect it, many of the mines are chiefly worked by levels or galleries driven horizontally into the sides of the hills, and but few of the pits exceed forty or fifty fathoms in depth, advantages which enable the minerals to be raised at a very cheap rate, and have therefore greatly contributed to the rapid progress made of late years in developing the resources of this important mineral district. Among its natural advantages, must also be numbered the proximity of limestone, which is largely used as a flux in the iron works, and of a coarse sandstone applicable to the construction of furnaces; the former is derived from the carboniferous or mountain limestone, which crops out from under the coal, all around the edges of the basin, and the latter from the beds of sandstone and conglomerate, which are interstratified with the coal. This peculiar association of mineral substances in such a manner that each adds to the value of the other, has often been noticed, as affording evidences of design in the structure of the globe; it is not however less deserving of our attention on that account.

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* This quantity greatly exceeds any former estimate of the make of iron in South Wales.

South Staffordshire Coal-field.—The coal district of Staffordshire is one of vast importance; the great thickness of one of its seams has already been noticed, and the manufacture of iron is here carried on to an immense extent, especially in the neighbourhood of Dudley, Wednesbury, Bilston, and Wolverhampton.* This coal-field is of an elongated elliptical form; its length from Stourbridge and Hales Owen on the south, to Rugely on the north, is about twenty-four miles, but its greatest breadth does not exceed five or six miles. Although, therefore, much smaller than some of our other coal-fields, its want of great superficial extent is amply made up by the various favourable circumstances which distinguish it, as the occurrence of the "ten-yard coal," the great abundance of clay-ironstone, and the proximity of excellent limestone and fire-clay. These advantages have contributed to render Staffordshire one of the most active seats of mining and manufacturing industry in the kingdom, and to raise the towns of Birmingham, Wolverhampton, Dudley, and other neighbouring places to their present wealth and importance.

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* The above description of the South Staffordshire coal-field is chiefly taken from a detailed account of this district, by the author of this work, published some time since in the "Mining Review." The following notice of the external appearance of the country, from the introductory portion of the same paper, will convey to the reader some idea of the most striking features of our coal and iron districts:—"To the tourist or casual traveller, this tract affords many objects of great interest, the effects of mining operations on a gigantic scale being everywhere palpably placed before his eyes, by the unusual appearance of the country, thickly studded with steam-engines, with blast-furnaces, and railways, and presenting evident marks of being completely honey-combed below, in the vast unsightly mounds of rubbish which are scattered in all directions upon the surface. The effect of this unusual scenery is not a little increased by the enormous volumes of dense smoke which hover round in all directions, and obscure the sky, while at night the view is rendered still more striking, the whole horizon being illuminated by the light of innumerable coke fires and blast-furnaces."

This coal-field possesses one very striking peculiarity in a geological point of view, the millstone grit and carboniferous limestone are entirely wanting, and the coal in the absence of its usual substrata, rests upon a more ancient formation of limestone. It differs also from our more northern coal-fields in containing comparatively few beds of sandstone, and these generally thin and of but small importance, the great mass of the formation being made up of shale beds, in which many seams of coal and ironstone occur, several of the former being of great thickness and value, while some of the ironstone measures are equally productive.

The general dip of this coal-field is towards the south, or rather the south-east, but it exhibits several remarkable curvatures and fractures of the strata, which are not only of much geological interest, but of great local importance, as bringing the beds of coal nearer to the surface, and allowing the underlying formation of limestone to be easily worked, although in its natural position so deeply seated as to be scarcely accessible for those purposes to which it is so largely applied. The main or ten-yard coal is situated about the middle of the series, which presents in all, eleven seams of coal, five being above, and five below the main bed. The northern half of the coal-field is entirely occupied by the lower seams of coal, which are chiefly worked to the north of a line drawn from Wolverhampton to Walsall, and therefore occupying the open tract termed Cannock Chase, and passing under the Marquis of Anglesea's Park, Beau Desert, their farthest known extent being near Rugely. The ten-yard coal crops out near Bilston, and extends from thence entirely over the southern half of the coal-field, where it forms the principal object of mining operation. Its extent is, however, much broken by the protruded masses of limestone and basalt, which appear at Dudley, Rowley Regis, and other places, while the effects of these elevations may be traced throughout the coal-field in the numerous faults and dislocations prevailing in almost every part of it.

The general continuity of the coal measures to the southward, is interrupted by two lines of elevation, one occurring near Walsall, the other near Dudley, and the underlying limestone is in both cases brought to the surface. Two anticlinal axes are thus formed; the most prominent and decided is, however, that at Dudley, which extends completely across the coal-field, separating it into two great troughs or basins. Each of these lines of elevation is marked by an eruption of basalt, but that to the south of Dudley is by far the most extensive and important.*

The most striking feature which this coal-field presents, is the extraordinary bed, or rather assemblage of beds, called the "ten-yard coal," which, as before observed, is confined to the southern half of the coal-field, and there forms the principal object of mining operations. The ten-yard coal is most extensively worked in the neighbourhood of Dudley, which lies nearly in the centre of it, and where it is found on both sides of the anticlinal axis formed by the limestone range, the depth from the surface being generally about 120 yards.

The depth of this bed of coal varies much, however, in different situations, being influenced both by its general dip, and the intervention of faults. It may be stated as usually occurring at from one to two hundred yards below the surface, which is the general limit of the depth of the collieries. In some of the older mines it was found, however, at a much less depth towards its outcrop, but these are now nearly exhausted. It may be mentioned, as a remarkable fact, that coal is stated to have been obtained near Wolverhampton, by *open cutting*, probably the only instance of the kind which has ever occurred in the kingdom. The ten-yard coal presents the very singular phenomenon of the successive deposition of carbonaceous matter, with scarcely a trace of the intervening earthy deposits which usually form such thick masses between the coal. We have here, therefore, a striking contrast to the usual circumstances attending the deposition of coal, the carbonaceous matter having been (if the expression may be allowed) in excess, while the earthy matter usually so abundant appears to have been almost entirely wanting.

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* "A diluvial deposit spread over the coal measures near Oldbury, is of a very remarkable character; it consists of loose sandy soil, containing besides the pebbles usually found in such situations, *rolled masses or boulders of coal*. This deposit is with much justice considered in the neighbourhood, as indicating the site of an ancient river. It may probably be referred to some ancient rush of water, occasioned by the altered drainage of the neighbouring country, at one of the great periods of elevation marked by the basaltic eruptions of Dudley and Walsall."

The ten-yard coal is generally made up of twelve or thirteen seams, of various qualities, each having its distinct appellation among the miners, and being separated from the others by a thin parting of shale. As regards the quality of the coal, it is deserving of notice, that the best is found occupying the middle of the bed, and about half its entire thickness, while the seams both above and below are very inferior, although extensively used in the neighbouring iron furnaces. The variety of circumstances under which the deposition of coal was carried on even within a very limited area, receives an admirable illustration from the singular phenomenon which characterises the crop of the ten-yard coal towards Bilston, and which is provincially termed by the miners, the "flying reed." The two upper seams of the bed become gradually separated both from the lower seams, and from each other, by the gradual interposition of thin wedge-like masses of rock, which at first form merely narrow partings between them, but increasing in size to the northward, at length present several beds of shale and sandstone, interpolated between the three beds of coal into which the ten-yard coal is then divided. The two upper beds, termed the "flying reed," rise quickly to the surface, but the principal mass of coal lying beneath them crops out still further to the northward. Large portions of this rich bed of coal are now exhausted, and great subsidences of the surface have consequently taken place above the excavations, as is often apparent from the cracked and inclined position of the houses and other buildings.

The beds lying above the ten-yard coal are but little worked, both from being thin, and from their proximity to such a much more abundant deposit. The beds lying below it are, however, worked very extensively in the northern part of the district, and have an average thickness equal to that which is generally observed in the north of England. The Staffordshire coal differs considerably from that of Newcastle, being of a less bituminous nature; it burns very readily, making an excellent fire, and leaving a residuum of white ashes. When used for the purpose of making gas it is found to afford from thirty to thirty-five per cent. less from a given quantity than the Newcastle coal, and its heating power is considered to be inferior in nearly the same proportion. From the peculiar nature of this coal the loss of weight sustained in coking is very great; it is generally, indeed, estimated to amount to full one-half.

The evolution of fire-damp from the Staffordshire coal is considerable, especially from the main bed, and formerly occasioned much loss of life, when the dangerous mode of exploding it by the "firing-line" was adopted. At the present time, owing to an improved mode of ventilation, and the use of the Davy lamp in situations where danger is apprehended, accidents of this kind are of less frequent occurrence. The great size of the excavations upon the thick coal, and the peculiar modes of working necessarily adopted in the getting of it, are often productive of accidents from the falling in of the loosened masses of coal, or of the roof itself.

The ironstone, although found in many of the strata, is chiefly worked in two thick beds lying below the main or ten-yard coal, and is the common clay-ironstone of the coal-measures. It generally occurs in septaria-like nodules imbedded in soft clay, forming seams from one to four yards or more in thickness. Iron pyrites occurs very abundantly in some of the beds of coal, and good specimens of columnar clay-ironstone are found near Wednesbury. About three tons of ironstone are used on an average in the furnace, to obtain one ton of pig-iron.

The shale and argillaceous beds, provincially termed "clunch," as previously observed, constitute the principal mass of the Staffordshire coal formation; the former exhibit the usual characters of coal-shale, but are frequently more compact and indurated, assuming the appearance of some of the older shales—a circumstance, no doubt, attributable to the proximity of the basaltic mass, which may be presumed to underlie the greater part of this coal-field, since, in addition to the erupted masses already noticed, it is found at a great depth in dykes and wedge-form masses in many of the coal mines. Some of the argillaceous beds of the coal-measures afford excellent fire-clay, and are extensively worked for this purpose, but the most valuable is that found near Stourbridge, from which the celebrated Stourbridge fire-bricks are made.

The sandstone is usually argillaceous, and is provincially termed "binds," or when much indurated, "rock binds." The small development of this rock appears to indicate a more quiet deposition than that which took place in the northern coal-fields, although occasional intervals of disturbance, probably contemporaneous with the eruptive movements of the underlying basalt, are clearly indicated by some of the sandstone beds, and a coarse conglomerate, expressly called by the miners "rough spoil." The sandstone beds afford in some situations excellent fire-stone, as at Gornal near Dudley, at Tipton, and other places. This material is extensively used in the construction of the iron furnaces, the hearths of which are formed of it, the upper part being built of fire-bricks. The entire thickness of the various beds constituting this coal formation is generally considered as somewhat exceeding 300 yards.

The faults which traverse the Staffordshire coal-field are, as before noticed, very numerous; the strata are, indeed, so much shattered and dislocated, that in any new trial much uncertainty exists as to the depth at which the seams of coal will be found. Many of the faults occasion a throw of more than fifty yards, and one near Bilston amounts to ninety or a hundred. Saline springs rise in some places from the coal-measures, and their situation, I have been informed, coincides with that of the faults, a circumstance calculated to throw much light on the origin of the rock-salt deposits of the adjoining county of Worcester.

In concluding this notice, some account of the present actual produce of the district under consideration may naturally be expected, and although no very accurate statement of the kind could be made without considerable labour, aided by numerous local sources of information, a sufficient approximation may be made to accompany the present general sketch.

The quantity of iron made in Staffordshire in the year 1827, has been stated from official documents, at 216,000 tons, the produce of ninety-five blast furnaces. In the following year (1828), the quantity of iron is stated in Marshall's Statistics, at 219,492 tons, also the produce of ninety-five furnaces, twenty-five being then out at blast. For the ten years which have since elapsed, I am not aware that any similar statements have been made, and from the well-known fluctuations in the iron trade, the quantity must have varied much. It is generally considered, however, that about a hundred furnaces are now in blast in Staffordshire, and if we take the weekly produce of each as being, on an average, but forty-five tons, which will probably be near the truth, it will give a total yearly produce of 234,000 tons of pig-iron. During the great demand for railway and other iron, which prevailed two or three years ago, it is probable that the quantity may even have exceeded this amount; while, in the intermediate period of depression, it must, doubtless, have fallen much short of it.

As regards the quantity of coal produced in Staffordshire, our means of information are less perfect, no statement of the amount having, I believe, ever been published. From the quantity consumed in the furnaces, it will, however, be possible to form at least an approximate idea of the total amount. If we assume that, on an average, six tons of coal are consumed in producing one ton of pig-iron, and this certainly does not exceed the fact, we shall have a consumption of 1,404,000 tons of coal annually in the smelting of iron alone. Of the 234,000 tons of pig-iron yearly produced, probably about two-thirds are converted into bar-iron, thus requiring a vast additional consumption of coal. Every colliery has one or more steam-engines for winding the coal ; most of them an engine for drawing water also, and in these engines the coal is most profusely, or rather, indeed, extravagantly used. When we add to these demands the consumption of the dense population of the neighbouring district, of the manufactories of Birmingham and other places in the vicinity, the quantity employed for burning lime and other minor uses, it will not, perhaps, be an exaggeration to double the quantity used for the iron furnaces alone, and to state the quantity of coal produced by the South Staffordshire coal-field as little short of 3,000,000 tons per annum.

It would occupy a far greater space than can be here devoted, even to glance at the varied and ingenious species of industry by which the vast population of the district is supported, all taking their rise from the subterranean produce of the coal-field under consideration. At Dudley, nails and various articles of hardware are manufactured; at Wolverhampton, locks and articles of steel; at Walsall, bits, stirrups, spurs, and articles of hardware; while at Birmingham, the emporium of the neighbourhood, the manufacture of trinkets, jewellery, fire-arms, and every species of hardware, whether delicate or massive, ornamental or useful, is carried on to an extent unparalleled in any other part of the world, and justifying the expressive epithet of Burke, who called it the "toy-shop of Europe." In addition to the characteristic manufacture of every town within the district, the universal occupation of making nails should not be forgotten. The business of the nailor is almost peculiar to Staffordshire, and, unlike most other manufactures, is carried on with patriarchal simplicity in almost every cottage throughout the southern part of the county.

The progress of this active scene of universal industry is greatly facilitated by the numerous canals which traverse the county in all directions, converging to Birmingham as their common centre, and by means of the Grand Junction Canal, communicating even with the metropolis. The operations of the mines and the furnaces are, of course, facilitated by innumerable local tram-ways, thus reducing, by all the powers of art, the cost of transporting the bulky produce of the soil to the spots where it is required. Staffordshire, however, unlike most other mineral districts, exports but little of her raw produce, nearly the whole being finally worked up on the spot, and exported in a manufactured state.

It will be seen that the vast industrial fabric at which we have now so briefly glanced, is entirely dependent for its existence on the enormous supply of coal produced by the neighbouring district; and the richest deposit of this mineral, the "ten-yard coal," has already been spoken of as partially exhausted. The question naturally arises, then, how long will the present supply continue, and the district be maintained in its present flourishing condition? To this important query a general answer only can be given. It is certain that the quantity of coal contained in the district has been greatly reduced, both by actual consumption, by unnecessary waste, and by unfortunate subterranean combustion; on the other hand, however, it is probable that the beds below the main coal may yet contain a large reserve in the northern portion of the coal-field, and even that they may hereafter in some cases be worked with advantage in places where the upper coal is now nearly exhausted; while (which is far more important) the peculiar geological features of the country indicate the probability of a great extension of the coal-measures beyond their present known limits. It will be seen that this coal-field, unlike many others, is not bounded by more ancient rocks which crop out from below and positively circumscribe its limits. It is, on the contrary, surrounded by the new red sandstone, below which a large portion of it dips, extending for an unknown distance, and existing at an uncertain depth. To this great extension of the coal-field we may look then for a supply for future ages, when the present known beds shall have become exhausted, and the trials which have been made within the last few years show that we shall not look in vain. It is understood that this interesting subject has been very ably investigated by Mr. Murchison, and will be fully treated on in his splendid forthcoming work on the "Silurian Region;" any further notice of it here would, therefore, be superfluous.*

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[*] The following note forms the conclusion of the paper from which the above account of the Staffordshire coal-field is taken. The subject is important, and deserves far more attention than is usually paid to it: some further general remarks will also be found at the end of this account of the coal formation:—

"Much greater economy in the working of coal has, fortunately, of late years been introduced in Staffordshire, and even the satisfactory prospect just noticed does not diminish its necessity; for, although there is every probability that the district itself may continue to be productive of minerals, long after the present working tract is exhausted, still the deterioration of existing property of every kind must be immense whenever the population and the seats of maufacturing industry shall gradually be obliged to settle in new localities, in consequence of the opening of new mines, and the exhaustion of the old ones. It must also be remembered that the present mineral tract can never return back to its primitive condition of an agricultural district—encumbered with mouldering piles of

FLINTSHIRE COAL-FIELD.—The Flintshire coal-field extends from a little south of Oswestry to the north-western extremity of the æstuary of the Dee, forming a long, narrow slip, having a direction nearly north and south. Its length is about forty miles; the ascertained breadth is inconsiderable, seldom exceeding three or four miles. The carboniferous limestone crops out from beneath the coal-measures to the westward; beds of shale, gritstone, and chert, intervening between the two formations. The coal-measures dip to the east or north-east; and are, in this direction, overlaid by the great formation of new red sandstone which prevails so extensively in the neighbouring counties of Cheshire and Lancashire. It is highly probable, indeed, that the Flintshire coal-measures may be continuous beneath the new red sandstone for an immense extent, so as to join the great Lancashire coal-field, and to form merely the opposite portion of it. This opinion has long been entertained, and has been, in some measure, confirmed by recent discoveries of coal in the intermediate tract. In this case, the supply of coal in the great manufacturing district

masonry, with enormous masses of slag and cinder, the produce of the iron furnaces, and with heaps of refuse from the mines, its aspect, when abandoned, will resemble that of an extinct volcano, and its value be literally reduced to nothing. Without wishing to lay an undue stress upon the future, it would, perhaps, be well were considerations like the foregoing to have some little weight in our coal districts, at least so far as to prevent unnecessary waste of that valuable substance, which, however abundant in this country, is still positively limited in its quantity, and absolutely incapable of reproduction."

Lancashire may be looked upon as almost inex-ustible, and a large addition must be made to all rmer estimates of the future duration of our coal-elds.

The Flintshire coal-measures crop out to the surface in a line passing near Oswestry, Chirk, Ruabon, Wrexham, Mold, and Holywell, and running for several miles nearly parallel to the æstuary of the Dee. They consist of the usual alternations of shale, sandstone, ironstone layers, and coal—the latter forming several thick and workable seams. The main coal, which lies towards the bottom of the series, is generally eight or nine feet thick, or sometimes more; the other seams varying from two to five or six feet; one of which, above the main coal, has been a good deal worked. The principal coal-seams occupy a thickness of not more than fifty or sixty yards, and incline at an angle of 12° or 15°, sometimes more. They thus pass under the Dee, within a short distance of their out-crop, and are not worked to any considerable depth. Extensive mines are opened at Ruabon, in Denbighshire, at Bagillt, in Flintshire, and in other places. The ironstone layers of this coal-field are most extensively worked towards the southern extremity, especially near Ruabon, where the British Iron Company has considerable works; northward, there are several foundries near Hawarden.

A small coal district occurs in the Isle of Anglesey, crossing it in a north-easterly direction, parallel to the Menai Strait: it rests upon the carboniferous limestone, and is worked to some extent, but is merely of local importance.

LANCASHIRE COAL-FIELD.—The Lancashire coal-field is one of great size and of vast importance, since it gives rise to the extensive manufactures carried on in that county, supporting, as they do, the populous towns of Manchester, Salford, Stockport, Oldham, Bury, Bolton, Blackburn, &c., places which monopolise the cotton trade of the kingdom. The boundary of this coal-field is very irregular: it extends from a little east of Liverpool, skirting the line of the Liverpool and Manchester railway, to Ashton-under-Line, a distance of about thirty-five miles; and covers an immense area to the north as far as Blackburn, including all the manufacturing district of Lancashire. From Ashton-under-Line a long, narrow slip appears to run southward for more than thirty miles, including Macclesfield in its limits.

This immense range of coal-measures rises to the surface towards the east and north, where the millstone-grit (here far more extensively developed than in the more southern coal districts) crops out from below them. The great substratum of the whole series is the carboniferous limestone of Derbyshire on the east, and of Yorkshire on the north. If we admit the continuity of this coal-field with that of Flintshire, before described, we may consider the western boundary to be formed by the carboniferous limestone of Flintshire and Derbyshire, and it must then be regarded as by far the largest coal district in England. The general dip of the coal-strata is to the west or south-west; and they are, in this direction, overlaid by the new red sandstone of Lancashire and Cheshire. The depth of the mines, in different parts of this great coal-field, differs much, but may generally be stated as varying from 120 to 170 fathoms.

YORKSHIRE, DERBYSHIRE, AND NOTTINGHAMSHIRE COAL-FIELD.—The great coal-field of Yorkshire, Derbyshire, and Nottinghamshire, is not inferior in extent to any of those previously described, since it covers an immense area, extending over the three counties above named. Commencing near Derby and Nottingham, on the south, it extends to a little beyond Leeds, and nearly as far as Bradford, on the north—being a distance of more than sixty miles; its average breadth towards the southern extremity does not exceed ten miles, but, proceeding northward, it increases to above twenty. The manufactures carried on in this tract are very considerable; and Chesterfield, Sheffield, Rotherham, Barnsley, Wakefield, Huddersfield, and Halifax, are included within its area; Derby and Nottingham being just without its southern extremity; and Leeds and Bradford close bordering upon its northern limits.

To the westward this coal-field rests upon the millstone-grit of Derbyshire and Yorkshire, beneath which crops out the carboniferous limestone forming the fine scenery of the former county, and extending from Ashborne, on the south, to Castleton, on the north. The general dip of the coal-strata is to the eastward; and, in this direction, they are lost beneath the zone of magnesian limestone which extends, with little interruption, from Nottingham to Sunderland, being itself overlaid by the new red sandstone of the central counties. The actual limits of the coal-field to the eastward cannot, therefore, be considered as well ascertained; and, from its great resemblance to the coal-field of Durham and Northumberland, and its exact coincidence of geological position, it may almost be considered, whether absolutely continuous or not, as the southern extremity of that important tract. To explain this view it may be observed that the substrata of both coal-fields are the same: we see the immense formation of millstone grit, which is so largely developed in the north of England, dipping below and supporting both, from beneath which emerges the same general foundation of carboniferous limestone, forming the well-known mountains and dales of Derbyshire, and similar bold and lofty tracts in Yorkshire, Durham, and Northumberland. Both coal-fields are also covered to the eastward by the same extensive zones of magnesian limestone and new red sandstone, thus forming on the great scale a general and perhaps continuous series of carboniferous beds interpolated between the older and newer secondary formations of the north of England.

This coal-field, from its inland position, has but little export-trade, but the quantity raised for the consumption of the great manufacturing towns situated within its area is very great. The seams of coal like those of the Durham and Northumberland field vary from one or two to five or six feet in thickness, and in some places are partially exhausted. The quality of the coal is bituminous and much like Newcastle coal, but rather inferior to it: the depth of the mines of course varies much according to their situation, but is generally very considerable.

WHITEHAVEN COAL-FIELD.—The Whitehaven coal-field extends along the coast from near St. Bees head to Maryport, a distance of about fifteen miles, and stretches inland to near Penrith, a distance of about thirty miles; the ascertained breadth is, however, inconsiderable, seldom exceeding three or four miles, except at Whitehaven, where the beds of coal dip beneath the sea, and therefore soon become inaccessible. The strata of this coal-field incline to the west or north-west; they repose upon the zone of carboniferous limestone which borders on the lake district of Cumberland and Westmoreland to the north, and dip below the tract of new red sandstone which forms the valley of the Eden.

The number of coal-seams is considerable; in some places as many as twenty-five have been observed, not more than six or seven, however, being workable. They vary from a foot and a half to ten or twelve feet in thickness, the aggregate thickness being estimated at thirty-five feet. The depth of the mines in this coal-field varies from 70 to 165 fathoms, and those upon the coast in the neighbourhood of Whitehaven and Workington are remarkable for being worked for a considerable distance under the sea. Owing to incautious working in this dangerous situation, a most unfortunate accident occurred about a twelvemonth since at Workington, by which twenty-seven lives were lost, and three valuable mines inundated by the sea, and thus rendered for ever useless and inaccessible. The mines of this district are not in so flourishing a state as formerly, and the export of coal is on the decline.

DURHAM AND NORTHUMBERLAND COAL-FIELD.—This coal-field extends along the coast from the river Coquet on the north, to the river Tyne on the south, where it proceeds inland, crossing and afterwards following the course of the Wear in a parallel line to the south for a great distance, embracing Newcastle, Durham, and Bishop's Auckland within its area, and terminating southward near Staindrop. The length from north to south is about 55 miles, and the breadth generally varies from 15 to 20 miles, or sometimes a little more, the western boundary being rather imperfectly defined. This coal-field possesses the great advantage of being situated upon the coast, and of being intersected by two navigable rivers, the Tyne and the Wear, thus enabling it to monopolise the supply both of the metropolis and the whole of our eastern and part of our southern coast.

About thirty seams of coal are known in this district, many of which, however, are too thin to pay for working; the two most valuable seams are distinguished as the "*high main*" and the "*low main*" coal, which are usually from six to seven feet in thickness, and are worked to an immense extent. The coal is very bituminous, and, from forming the principal fuel of London and the neighbouring counties, is too well known to require further notice. The seams of coal are interstratified with numerous beds of sandstone and shale, but the layers of clay ironstone, so abundant in the more southern coal-districts, are here comparatively rare and unimportant. From evidence before a Committee of the House of Commons it appears that the aggregate thickness of coal in the collieries near the Tyne amounts to thirty-two feet, while in those on the Wear it is about twenty-five feet.

The general dip of the Durham and Northumberland coal-field is from west to east, the strata cropping out in succession to the west and north-west, and being underlaid by the millstone grit and carboniferous limestone. The central or deepest part of the basin is in the vicinity of Jarrow, near South Shields, where the "*high main*" coal is found at the depth of 160 fathoms below the surface.

The south-eastern part of this coal-field is overlaid by the magnesian limestone; and, as the coal-strata dip below the latter rock, and are soon buried beneath a vast thickness of it, its limits in this direction are wholly unknown, as well as those of that large extent which was before noticed as bordering on the coast, and which dips under the sea. Although some little workings had long been carried on upon the coal, immediately below the edge of the magnesian limestone, till within the last few years no attempt had ever been made to penetrate this formation at a distant point, with a view of reaching the coal-measures presumed everywhere to exist at a great depth below it, but not experimentally ascertained to do so. The solution of this important problem, interesting equally in a geological and practical point of view, was undertaken by an enterprising individual, Mr. Pemberton, in 1826. Relying confidently on the order and succession of the strata, as established by geological investigations, he persevered in sinking for eight years, when, after penetrating the magnesian limestone and the upper unproductive beds of the coal-measures, he at length reached a workable seam of coal, at the depth of 263 fathoms. Having thus experimentally established the order of the strata, the pit is still sinking with a view to reach another valuable seam of coal, which it is expected will be cut at a greater depth. This remarkable pit, which is much deeper than any other coal-mine in Great Britain, has now attained, according to a late statement, the depth of about 290 fathoms, or 1740 feet.

The Durham and Northumberland coal-field is very much dislocated by faults; there is, indeed, scarcely a colliery in which several do not occur, always throwing the strata out of their original continuous position, and placing them at different levels on either side. These faults or dykes have various degrees of inclination, but usually approach the perpendicular, and they not unfrequently cross or branch off from each other; they are generally filled either with clay or with sandstone, are sometimes many yards wide, sometimes much narrower. The most important and best-known fault in the district is the "*main*" or "*ninety-fathom dyke*," which traverses the strata in a north-easterly direction to the north of the Tyne, near Newcastle, and throws down the strata for a perpendicular distance of *ninety* fathoms on its northern side. Other considerable faults branch off from this dyke to the southward, altogether presenting a most extraordinary picture of subterranean disturbance.

From the above faults or dykes, which are merely rents or fissures subsequently filled up with mineral matter from the abrasion of the neighbouring rocks, we may very appropriately turn to the basaltic dykes which traverse this coal-field—those protrusions of melted rock which were forced upwards by the deeply-seated incandescent mass, whose eruptive power had rent and fractured the strata in the manner just described. Many of these basaltic dykes occur in the Newcastle coal-field; the basalt is generally black and coarse-grained in its texture, and the beds of coal in its vicinity are uniformly converted into a *coke* or *cinder*, locally termed "*cinder-coal.*" The most remarkable basaltic dyke occurs in the southern part of the coal-field south of Bishop's Auckland, and running a little south of east, crosses the Tees between Yarm and Stockton, and traverses the oolitic strata of Yorkshire to within a few miles south of Whitby, being thus traced for a distance of nearly 60 miles. Two other great basaltic dykes cross this coal-field, one a little south of Durham, the other north of the Tyne, and smaller ones are of frequent occurrence.

Closely connected with these faults and basaltic dykes is the extensive denudation which this coal-field has suffered, and which has swept away large masses of the strata together with considerable portions of the included beds of coal. It is evident that, contingent upon the great dislocations of the strata before noticed, whether produced by elevation or subsidence, there must originally have been large elevated masses rising like islands above the general level of the country, and often containing valuable seams of coal. Not only in this coal-field, but in all others, these masses have been entirely swept away, and have left no marks whatever of their existence in the present configuration of the surface. But a far greater destruction of the coal-strata than this has been occasioned by the excavation of the valleys traversing this district, most of which are actually cut or *excavated* through the coal strata, immense tracts of which have been thus completely removed and lost, together with the included beds of coal. Immense denudations of this kind have given rise to the valleys of the Tyne, the Wear, the Derwent, and the Teame, the two former of which completely cross this coal-field, and, from the length and breadth of these excavations, cutting as they do completely through the upper seams of coal, the consequent waste of this mineral must have been prodigious. The overwhelming rush of waters by which these extensive denudations were effected may be referred partly to general movements of the land during its elevation, and partly to the agitation which must have been occasioned by those great subterranean movements which gave rise to the numerous basaltic dykes, and faults or dislocations consequent upon them, which, as before noticed, traverse this coal-field.

The extensive removal of the coal-strata of which we find evidence in every coal-field, and more especially the singular fact of the entire disappearance of those portions either uplifted by faults or left standing in isolated masses by subsidence, has long been correctly ascribed to denudation; still but little attention was paid to the precise circumstances under which this action took place, thus leaving the subject involved in some obscurity. It has, however, latterly attracted the attention of Mr. Bakewell, who has considered this phenomenon at length, and offered a very satisfactory explanation of it. The causes which he assigns are, "first, the soft and yielding condition of the submerged strata, that had never been indurated by drainage; and, secondly, the violent action of water upon them, when they were suddenly broken and forced upwards, but were still beneath the surface of the ocean." Under these conditions it is easy to understand the complete removal of large masses of coal, together with the enclosing layers of rock.

Although the coal-strata of this country have generally suffered much from denudation, the destruction of coal arising from this cause in the Durham and Northumberland coal-field has been the most considerable. The extent of coal swept away as before noticed, by the excavation of the great valleys intersecting it, has been prodigious, as will readily be seen on referring to a map of the country, and considering that they form deep indentations through some of the most productive of the upper coal-strata. We have it, indeed, on the high authority of Dr. Buckland, given in evidence before a parliamentary committee, that, to the westward and southward of Newcastle, not less than one-half of the uppermost and best beds of coal have been destroyed by denudation.

As the Durham and Northumberland coal-field is more extensively worked than any other in the whole world, and its geological structure has thus been very fully explored, and presents the characteristic phenomena of our coal-districts in a clear and striking point of view, the preceding sketch has been given as fully as our limits will allow; and it cannot be more appropriately concluded than by the following parliamentary returns of the quantity of coal shipped from the three ports which afford an outlet for the mineral produce of this important district. It may be observed that the returns are those of the last year (1837).

	Tons.
Newcastle . . .	2,392,494
Sunderland . . .	932,135
Stockton . . .	1,145,837
Total . .	4,470,466

Thus it will be seen that about four millions and a half of tons are annually shipped from this great coal-field, being more than half the quantity shipped from all our coal-fields together; the total shipments for the year 1837 amounting to 8,204,301 tons. The coal shipped from Newcastle is brought down the river Tyne, that from Sunderland down the Wear;

Stockton is chiefly supplied by railways which have been constructed within the last few years for that purpose, and afford an outlet to the southern part of the coal-field.

GREAT SCOTCH COAL-FIELDS.—The coal-formation of England, as will have been seen from the preceding description, spreads over a large portion of the country, extending almost from its southern to its northern extremity; in Scotland, on the contrary, this formation is entirely concentrated in a broad zone extending from the eastern to the western coast, from the Firth of Forth to the Frith of Clyde. The tract of country thus occupied by the great coal-formation of Scotland extends, though not continuously, from east to west, for about a hundred miles in length, and varies from thirty to forty miles in breadth, being widest at the western extremity, and including within its area Edinburgh, Stirling, Glasgow, Paisley, Lanark, and other considerable towns. Viewed on the great scale, this extensive area occupies an immense valley or depression, which separates the elevated ranges prevailing in the north of Scotland from those extending southward into the border counties. Its physical geography is also strongly marked by the deep indentation of the two great estuaries of the Firth of Forth and Frith of Clyde, and by the valley through which the river Clyde flows into the latter.

The geological features of this immense coal-field are no less remarkable than its physical geography; it is distinguished by the immense development of trappean rocks which occurs within its area and around its borders, by the occurrence of interstratified beds of limestone, and by the smaller extent of the usual substrata, the millstone grit and mountain limestone, which attain so much importance in the neighbouring coal-fields of the north of England. Old red sandstone and slate appear to constitute the general basis of the coal-strata, but over extensive areas basaltic and other trappean rocks are found to prevail beneath them.

In a general point of view the strata of this immense coal-field, or rather perhaps assemblage of coal-fields, crop out to the north and south against the sandstones and slates which rise from beneath them in those directions, and of course incline towards the opposite points, but it will be readily conceived that every possible irregularity must take place over so extensive an area, and one in which igneous action has been so largely experienced.

The general section presented by this coal-field consists, like that of most others, of alternations of sandstone, shale, fire-clay ironstone, and coal, to which, unlike the English coal-measures, must be added several beds of limestone. It appears, according to Mr. Farey's report, that the coal-measures are made up of 337 distinct beds, of which no less than eighty-four are seams of coal, while seven are limestone strata. The total thickness of this immense carboniferous system is estimated at about 5000 feet, or one mile perpendicular.

The ironstone beds occurring in the Scotch coal-field are extensively worked, especially in the neighbourhood of Glasgow, where there are many iron furnaces in activity; and much attention has latterly been drawn to this district by the successful introduction of Mr. Neilson's invention, the "hot blast" process, which has effected an extraordinary saving of fuel. The coal-districts are of course the chief seat of the Scotch manufactures, and the flourishing and populous towns of Glasgow and Paisley owe their present wealth and importance to the beds of coal in their vicinity.

MINOR COAL-FIELDS OF ENGLAND.—The extent, geological structure, and other peculiarities of those important tracts in which nature has concentrated that vast amount of mineral wealth which has contributed so greatly to raise Great Britain to her present high political rank, and has formed the prime mover of all her manufacturing industry, have now been pointed out at very considerable length; but before dismissing the subject of the coal-formation it will be necessary briefly to notice several of our less extensive and important coal-fields, which, although generally much worked, are, from their size or situation, merely of local value. Although there is scarcely one of these which, if minutely described, would not present many features of geological interest, or which, if situated in any other country, would not be considered of great importance, it may be stated in general terms that, with one exception, they all present striking features of resemblance to those great types which have already been so fully noticed, and will not, therefore, require any lengthened description here.

SHROPSHIRE.—Shropshire presents several of these minor coal-fields, which are situated in a north and south line following the course of the Severn, and extending from a little south of Bewdley almost to Newport. To the westward they rest upon transition limestones and other rocks connected with the old red sandstone and its subjacent slates, and to the eastward are overlaid by the new red sandstone of the valley of the Severn. The coal-district of Coalbrookdale is the most important of these tracts; from its westerly dip and general geological features, it may probably form a continuous portion of the Staffordshire coal-field, the intervening part being covered up by new red sandstone. Coalbrookdale and its vicinity is well known as a seat of the iron manufacture.

WARWICKSHIRE.—The Warwickshire coal-field occupies a long narrow tract extending from near Coventry on the south to Tamworth on the north, a distance of nearly twenty miles, but the breadth does not exceed three or four miles. The strata of this coal-field are thrown into a high angle of elevation corresponding to that of the older subjacent limestones, which rise from below them to the eastward; the general dip is to the westward, and in that direction they incline beneath the new red sandstone, and may probably be continuous with the opposite coal-field of Staffordshire. The principal bed of coal is fifteen feet in thickness.

LEICESTERSHIRE.—The Ashby coal-field is of considerable size, since it extends not less than five or six miles in all directions around the town of Ashby-de-la-Zouch, and considerable workings are carried on within its area. The strata crop out to the east and north, where they rest on the carboniferous limestone, finally reposing in dislocated masses upon the slates of Charnwood Forest. In one part of this coal-field a seam of coal occurs which is from 18 to 20 feet in thickness, and the pits have attained the depth of nearly 200 fathoms.

NORTH STAFFORDSHIRE, &c.—The North Staffordshire coal-district is situated near Newcastle-under-Line; it has been considerably worked, and is chiefly important as forming the seat of the potteries. The beauty and utility of the manufactures carried on so extensively in this district must be too well known to require comment.

Several other small coal-fields, chiefly in the north of England, might still be enumerated, but to enter into any details of them would exceed the limits of the present volume, a very considerable and indeed almost disproportionate space having already been devoted to the description of our coal-districts, forming as they do the seats of our manufactures and the grand sources of our national wealth.

CULMIFEROUS DEPOSITS OF NORTH DEVON.—Before quitting the coal-formation, there is, however, one very remarkable tract in North Devon, the existence, or rather true relations, of which have lately been made known by Mr. Murchison and Professor Sedgwick, which will require a brief notice. This remarkable tract exhibits a series of shales and sandstones, with occasionally vegetable impressions and thin seams and traces of "culm" or anthracite, and is considered by these gentlemen as being the local representative of the coal-formation, or in fact a barren unproductive coal-field. Although an object of much geological interest, further details would here be out of place, other than that this singular carbonaceous deposit is greatly bent and contorted, and when it approaches the northern border of Dartmoor the beds are tilted by the granite of that tract, which is, therefore, greatly contrary to former ideas, of more recent date than the coal-measures.

COAL-FIELDS OF IRELAND.—The great extent to which the coal-formation of England, Wales, and Scotland has been worked in every locality where it occurs, has made us very accurately acquainted with its extent, the number, thickness, and quality of the seams of coal, and indeed with almost every other nteresting particular respecting it, as will have been seen in the foregoing notices of our coal-districts; with Ireland, however, the case is unfortunately very different; a few years ago only, little beyond the bare fact of the existence of coal in that country was known; and our information, although now much more perfect, has been chiefly derived from the labours of two distinguished geologists, Mr. Griffiths and Mr. Weaver, who have made us acquainted with the internal structure of that country with an accuracy and precision deserving of the most unqualified approbation.

Coal is abundantly distributed in Ireland, where there are four principal coal-districts, the Connaught and Ulster, which produce bituminous coal, and those of Leinster and Munster, which produce only stone-coal, or the carbonaceous variety.

The Connaught coal-district occupies a large extent of country surrounding Lough Allen, in the County of Leitrim; it contains good bituminous coal, but has not yet been very extensively wrought. Numerous beds of clay-ironstone of excellent quality occur in this coal-field, which has occasioned the establishment of iron-works at Arigna, near Lough Allen, which have not, however, led to any very successful results. There are also some old abandoned iron-works at Drumshambo in the same vicinity. The general substratum of this coal-field is the carboniferous limestone.

The Ulster coal-district is of much less importance than the Connaught; the coal is of the same quality, and chiefly worked at Dungannon and Coal Island; perhaps both this and the Connaught coal-field may be looked upon as the western prolongation of the great Scotch coal-field, previously described.

The Leinster coal-field is very extensive: it occupies a large portion of Kilkenny and the adjoining counties, and produces the species of stone-coal, or anthracite, generally known as "Kilkenny coal." The general substratum of this coal-field is the carboniferous limestone, the undulating surface of which divides the coal-strata into three separate areas.

The Munster coal-field, which also produces stone-coal, is situated to the westward of the former, extending over portions of Limerick, Kerry, and Cork: it is considered to be the most extensive coal-district in Ireland, but, like the others, has been but little worked.

MINING IN IRELAND.—The foregoing notice, brief as it is, will be sufficient to show the very extensive development of the coal-formation in Ireland; and, although these coal-fields do not appear to contain such thick and valuable beds of that mineral as those of England, it cannot be doubted that the working of such large and virgin coal-districts, with beds in many places cropping out to the surface, will be attended with immense benefit to the country. The great mineral wealth of Ireland, not only in coal, but in lead and copper also, is now beginning to attract the attention of English capitalists, and in several instances very successful results have attended the opening of mines in that country. We may thence hope that the development of the mineral resources of Ireland has now fairly commenced, nor could any measures be taken which would be more effectual in alleviating the distresses of that unfortunate country, than by thus affording extensive and permanent employment to its population in extracting the valuable, but hitherto neglected, produce of the soil, to the mutual benefit of themselves and of the English capitalists who may be induced to employ them.

IMPORTANCE OF OUR COAL DEPOSITS.—It might appear almost superfluous to point out the vast utility and importance of the series of rocks described above, under the name of the "coal-formation," yet there are probably many persons who are scarcely aware of the full extent of the advantages which Great Britain has derived from her geological structure embracing such valuable and extensive deposits of this mineral. It has been observed by an able writer, speaking of our coal-formation, "The manufacturing industry of this island, colossal as is the fabric which it has raised, rests principally on no other base than our fortunate position with regard to the rocks of this series; should our coal-mines ever be exhausted, it would melt away at once."

Bold as this assertion may at first appear, it requires but little reflection to be convinced of its truth and justice. The steam-engine, the motive power of our mines and manufactories, depends upon the abundance and cheapness of coal for its existence; and, deprived of this mighty source of her present commercial energy, England could no longer supply the wants of her dense and increasing population; foreign produce would cease to flow into this country in exchange for our superabundant manufactures; labour would no longer find adequate employment; forests must overspread the poorer lands to furnish fuel for our diminished population, civilization itself might retrograde, and England would stand no higher in the scale of nations than what is due to her scanty geographical boundaries. Such, however, is the liberality with which nature has supplied Great Britain with this most valuable mineral, that, even at our present enormous rate of consumption, a vast period may yet roll on before any serious diminution in the supply begins to be felt.

PROBABLE DURATION OF OUR RESERVES OF COAL.—On concluding our view of this most important series of rocks, the extensive development of which within the area of the British Islands, as before noticed, has mainly given to this country her present wealth, her commercial importance, and her political power, there is a question to which allusion has just been made, which must have occurred to every reflecting mind, and which is not undeserving of an answer—When will our coal mines be exhausted?—how much longer will they be able to supply our present enormous consumption of this mineral?

It will have been observed, on perusing the foregoing pages, that symptoms of exhaustion have been noticed in several of our coal-fields, and it is very certain that, within their present known limits, another century or two, in some cases even less, will make fearful havoc in their remaining beds of coal. On the other hand, it will have been observed that many of our coal-fields, especially in the central counties, are overlaid in one or more directions by the new red sandstone, and therefore their actual extent is in great measure unknown, but may, as was noticed in several cases, be much greater than is at present ascertained. In attempting, therefore, to form any estimate of the duration of our coal-fields, at the present rate of exhaustion, we must keep in view not only their actual remaining stores, but their probable future extension;

the former being known with tolerable correctness, while the latter has as yet been very imperfectly investigated. It is the opinion of the writer that a vast extent of our coal-formation, in many cases, even greater than its present known area, still remains to be discovered—that our central counties are little else than an enormous tract of coal-measures, buried for the most part beneath the new red sandstone, and other more recent rocks, and only appearing here and there in uplifted masses, where they rest upon protrusions of the older rocks. Whether, however, the quality and abundance of the coal continues without deterioration or decrease below these hidden tracts, and under what circumstances it might become profitable to work them, of course at a much higher rate of cost than at present, are questions of great interest, but which cannot here be ventured upon.

The great storehouse for future ages, as has already been noticed, is undoubtedly the South Wales coal-field, the reserves contained in which have been variously estimated, but may probably be considered as sufficient to supply the whole consumption of England for about 1000 years. The coal remaining in the Durham and Northumberland district has been estimated as sufficient to supply our present consumption for about 400 years, and we may fairly consider the reserves of the Yorkshire, Lancashire, Scotch, and other remaining coal-fields, as considerably exceeding the aggregate of these two. It is pretty certain, therefore, that our present rate of consumption may be maintained for considerably more than 2000 years, independently of the probable discovery of coal beyond its present known limits, before noticed.

Although there are, undoubtedly, circumstances which may tend to vitiate the foregoing estimates, such as all parts of the same coal-field not being uniformly productive, the cropping out and final termination of particular seams far within the general area, the waste occasioned by faults, &c., these have been so far allowed for that no very serious error can have been made, and we are therefore fully warranted in anticipating the continuance of our present supply for a period of from 2000 to 3000 years; while, by working inferior seams of coal, and making discoveries of coal-tracts covered up by more recent strata and at present unknown, an indefinite extension of this period may be obtained.

This view, although very satisfactory, ought not, however, to encourage the enormous waste of this invaluable mineral, which has unfortunately always prevailed: *our climate is fixed and unalterable, our population is dense and increasing;* certainly then waste ought not to be encouraged of that stock of fuel which *can alone ameliorate the former, and afford employment to the latter.* Perhaps the true way to view the subject is, however, as a local one, for in that case it comes home more nearly to our own interest and our own concerns. The duration of the Newcastle coal-field has been estimated at 400 years (by another authority at only 360), but it is certain that, before a quarter of that time has elapsed, many parts will be exhausted, much property now of great value will be nearly worthless, and the South Wales district will then begin to prove a formidable competitor in the export coasting-trade, which must from that time experience a decline. In the same manner, if we look to the Staffordshire coal-district, rich portions of which are already exhausted, we shall observe that another century will there produce important changes, for, although new tracts of coal may be discovered, the price of the fuel will be much enhanced, to the serious injury of the immense manufacturing population of Birmingham and the neighbouring towns, which are entirely dependent on the cheapness and abundance of coal. However large, therefore, our supplies of coal may appear, there can be no justification of the enormous waste which unhappily prevails in our coal districts, and which must be productive of serious eventual injury to those localities.

It should in fact be remembered that, however remote the *final* exhaustion of our coal-fields may be, that period of exhaustion will be preceded by a long *progressive decline*, from the commencement of which, great individual interests will begin to suffer; nor can this evil, although in some measure a partial one, be regarded as otherwise than a national calamity, since it will deprive a large industrious population of their hereditary employment, and prove a gradual drying up of the sources of national wealth. It has been beautifully and expressively said of coming events that they "cast their shadows before," and we may feel assured that a long and gloomy shadow will be thrown by that period, remote though it be, which has now been contemplated. The mineral resources with which Providence has so largely gifted our country are vast, indeed, but *not* infinite, nor can any extenuation be offered of the reckless waste of that which Nature doubtless intended should be the inheritance of a future and distant generation. Greater economy, both in the working and consumption of coal, has been latterly introduced in some of our coal-districts, and it would be well if the preceding arguments were to receive that attention which every geologist must feel is due to them. In conclusion, I would observe, that it is not the mere possession of enormous stores of coal which is of any value to us as a manufacturing nation, but the *cheapness and abundance with which this fuel can be raised, compared with other countries*; and the moment that this balance is turned against us by the exhaustion of our richest and most accessible deposits, from that moment our manufactures must permanently decline, however large the reserves may be which yet remain.

MILLSTONE GRIT.—The upper carboniferous portion of the coal-formation, expressively termed the "*coal-measures*," has been very fully described in the preceding pages; we now therefore proceed to consider those rocks which form the base of the coal-strata, and which, although seldom containing coal of much value, are geologically classed with the former. The great sandstone-formation occurring below the coal-measures, as before noticed, is called the "millstone grit," no doubt from its often affording, especially in Derbyshire, an excellent material for millstones. Its usual appearance is that of a conglomerate rock (sometimes very coarse), consisting chiefly of quartz pebbles of different sizes, held together by an argillaceous cement: some of the beds are, however, of a much finer texture, considerably resembling the sandstones associated with the coal-measures. Beds of shale, similar to those before described, often occur in the millstone grit, and most abundantly in the lower beds resting on the mountain limestone. In this part of the series they often become of great thickness and importance, and, as before noticed, are termed the limestone shale. (See Plates 2 and 3.)

The millstone grit and its associated shale occur chiefly in the northern counties, where they spread over a very large extent of country: commencing in Derbyshire, this formation emerges from below the coal-measures, and forms a broad zone partially extending around them, in Lancashire, Yorkshire, Durham, and Northumberland.

This formation contains but few fossils, chiefly of marine origin. Its mineral contents are of considerable importance, many of the most productive lead veins in this country occurring at or near the junction of the gritstone and the subjacent mountain limestone, which is well illustrated in Plate 3, which gives a section of a lead-mine thus situated. This is particularly the case in Flintshire, Derbyshire, Yorkshire, and the other great lead-mine districts in the north of England.

The gritstone forms an excellent material for bridges and other erections, where strength and durability are required. It is extensively quarried in Derbyshire, Yorkshire, Durham, &c., and furnishes the principal material for the foot pavements of London.

The tracts formed by this rock are generally very mountainous and barren, rising to a much greater height than any of the formations previously described. The range of mountains extending through Derbyshire and Yorkshire, into Durham and Northumberland, is chiefly formed by it: many of these summits attain an elevation of between two and three thousand feet, the base of the mountains being generally carboniferous limestone, and the summits capped with gritstone. The thickness of this formation varies considerably in different situations: it has, however, been supposed to average about seven or eight hundred feet.

CARBONIFEROUS, OR MOUNTAIN LIMESTONE.—The prevailing feature in this formation is a compact limestone, consisting principally of carbonate of lime, but occasionally combined with accidental ingredients, as iron and bituminous matter. Its texture is more uniform than that of most of the preceding rocks, being generally crystalline, though less perfectly so than that of the older primary limestones. The colour is usually whitish, grayish, or approaching to black. Interstratified with this limestone are thin beds of chert, and sometimes inferior seams of coal, beds of shale, and sandstone: these associated beds occur chiefly in the most northern counties, where the limestone, instead of forming a thick homogeneous mass, is much interstratified with shale and sandstone, and proportionally reduced in thickness.

LOCALITIES.—This rock occurs in many parts of England, occasionally forming, as before noticed, vast troughs or basins, enclosing our great deposits of coal, with the accompanying gritstone and shale. It occurs in Somersetshire, forming the Mendip hills; it forms the fine scenery of the Avon, near Bristol, and skirts the coal-fields of Gloucestershire and South Wales. It crops out in a similar manner from below the coal-fields of Flintshire and Denbighshire, forms the Peak Forest and the mountainous districts of Derbyshire, and occupies extensive tracts in Lancashire, Yorkshire, and all the northern counties, especially Northumberland, where it spreads over an immense area. It forms a large tract in the central part of Ireland, which is remarkable for its plain unvaried surface, contrasting strongly with the bold character of the mountain limestone in England. The great limestone-district of Ireland extends east and west quite across the country, from Galway to Dublin, and occupies an equally extensive area from north to south, reaching from Clonmel to Enniskillen; thus forming the base of the principal Irish coal-fields. The upper beds are of a grey colour and crystalline texture; the lower ones black, impure, and interstratified with shale. In Galway and Kilkenny this limestone affords handsome black marbles. This rock occurs in Belgium and several other countries of Europe, and in America.

Organic Remains.—The organic remains of the mountain limestone are of marine origin, consisting chiefly of *corals*, *shells*, and *encrinites* ; the latter are in some places so abundant as to constitute a large proportion of the whole mass of particular strata, and to have occasioned the name of "*encrinal limestone*" to be applied to them. The most numerous shells are *Terebratula*, *Producta*, and *Spirifer* : the corals are often very beautiful, and the organic remains of this rock, being converted into hard limestone, are very perfectly preserved.

Mineral produce.—The limestones of this series receive a good polish, and are therefore much used as marbles. The principal quarries are in Derbyshire, and some of the marbles are singularly variegated by the enclosed encrinites, shells, and other petrifactions.

This formation derives its chief importance, however, from containing our great deposits of lead-ore : it furnishes also some other metals, as zinc and copper, but in less abundance. Lead-mines are extensively worked in rocks of this series in Flintshire and Denbighshire, and also in Derbyshire and Yorkshire. The great lead-mine district surrounding the town of Alston in Cumberland is in this formation. These great metalliferous deposits, like most others in Great Britain, are chiefly found in what are termed *veins* or *lodes*. They may generally be described as long, but narrow fissures in rocks, going down, either perpendicularly or nearly so, to an unknown depth, and filled with a variety of mineral substances, as quartz, calcareous spar, fluor spar, &c., but containing here and there large quantities of the metallic ores, in irregular masses, or, as they are termed by the miner, "bunches." Their direction in this country is nearly east and west, and they frequently *throw* the strata up or down in the same manner as the faults, before noticed. The nature of mineral veins will be more clearly understood by reference to fig. 3, Plate 2, and also to Plate 5, which represents them as seen in a section crossing their line of direction. The annual produce of the lead-mines of this country may be estimated at the present quantity of about 48,000 tons.

Rich hæmatitic iron is obtained from this formation near Ulverston in Lancashire, and many of its coal-seams admit of being worked in some parts of Northumberland, although much less valuable than those beds which occur in the coal-measures.

SCENERY.—The districts formed by this rock, as its name implies, are generally mountainous; and from this circumstance, as well as the large proportion of calcareous matter which it contains, are often barren, producing merely a short herbage. The valleys, however, are usually rich, and afford excellent pasturage. This rock deserves particular notice on account of the fine scenery which it affords, as well as the remarkable phenomenon it so frequently presents, of caverns, and other subterranean passages, which often engulf the streams which traverse it, affording them an underground channel, sometimes miles in length. It may indeed be stated that very nearly all the natural caverns in England occur in the mountain limestone; the most remarkable of them are situated in Derbyshire and Yorkshire. In the latter county the phenomenon of streams pursuing a subterranean course is of very frequent occurrence. The water is generally received into a large funnel-shaped cavity, (provincially termed a "*swallow*,") and, after disappearing, may often be traced again issuing at the basset of some inferior stratum, at a considerable distance lower down the valley. The scenery of these valleys (or "*dales*") is often very picturesque; they are narrow and winding, bounded on each side by lofty hills, rising abruptly, and broken by numerous rocky precipices, or "*scars*," the wild and barren appearance of which forms a fine contrast to the verdure and cultivation below. The water flowing over the limestone is peculiarly clear and transparent, and, as the streams often traverse the successive outcrop of the strata, numerous waterfalls are thus formed, adding much to the beauty of a scenery, in a great measure peculiar to the mountain limestone districts.

OLD RED SANDSTONE.—This rock is so named in order to distinguish it from a sandstone very similar in many respects, but belonging to a much more recent geological period, and thence termed the "*new red sandstone*." It will therefore be convenient to remember that the great coal-formation of this country, with its associated millstone grit and carboniferous limestone, are usually interposed between these two deposits of sandstone, the *old* red sandstone occurring immediately below, and forming the *base* of the series, while the *new* red sandstone occupies a position immediately *above*, and often forms a partial *covering* to it.

The appearance of this rock is usually that of a conglomerate sandstone of a reddish colour, chiefly formed from the abraded fragments of the older siliceous rocks, especially granite, and often held together by an argillaceous cement. The texture is variable: it sometimes appears as a coarse conglomerate or breccia, sometimes as a fine-grained sandstone, and often, in its lower beds, as a slaty rock much resembling greywacke, which it then, by insensible gradations, passes into. It contains thin beds of argillaceous matter, and sometimes those singular concretions of calcareous matter, which are locally termed "*cornstone*."

In England this formation is very extensive, though chiefly occurring in one district, Herefordshire and the adjoining counties of Monmouth and Brecknock. It occurs sparingly in North Wales and some of the northern counties; it underlies the coal formation in several parts of Scotland, and is therefore found in those districts where, as before noticed, the coal-fields chiefly occur.

This rock contains a few organic remains which indicate a marine origin, and its mineral contents are unimportant. The district formed by it in Herefordshire and the adjoining counties is bold and mountainous, many parts of it being remarkable for their fertility; some of the beds afford stones for paving and building. No general average can be given of the thickness, which is commonly very great:

it may indeed be said to vary from a few hundred to several thousand feet.

SILURIAN ROCKS.—The class of rocks termed "Silurian," from their occurring principally in the border counties of England and Wales, anciently inhabited by the *Silures*, has been very recently instituted by Mr. Murchison, having been taken by him from the upper portion of the assemblage of rocks hitherto passing under the vague denominations of *greywacke* and *transition limestone*—names which, in the course of a few years, will probably disappear before a new and more precise classification of this hitherto neglected portion of our geological series. It appears that Mr. Murchison's classification will embrace three principal series of rocks, the *upper* and *lower Silurian*, and the *Cambrian*, each having many subdivisions; but the work, which will develop his views on the subject, as well as show the exact boundaries and localities of each, has not yet appeared. The subdivisions of the Silurian rocks are—

The *Ludlow rocks*, consisting of beds of dark micaceous sandstone, beds of shale, and a grayish subcrystalline limestone. These rocks are chiefly found in Brecknockshire and other counties of South Wales, and in some parts of Worcestershire, Shropshire, and the adjoining counties. The organic remains consist of *corals*, with *orthoceratites terebratula*, and other shells. The thickness is considered to be nearly 2000 feet.

The *Wenlock* and *Dudley rocks* consist of grayish limestone and shale, occurring in nearly the same localities as the former class, and recognised also in Ireland, France, and Germany. The organic remains are numerous and highly interesting, chiefly the coralline group termed *crinoidea; spirifer* and *producta* are abundant, but the most remarkable and best known is that singular fossil the *Calymene Blumenbachii*, generally called the *Dudley Trilobite*, from its being found in the neighbourhood of that town, which affords one of the finest examples of the class of rocks we are considering. The venerable ruins of Dudley Castle stand upon the limestone rocks of this series, which have here been forced up by volcanic agency, in highly-inclined and contorted strata, through the superincumbent coal-measures by which they are surrounded. The thickness of this group is estimated at about 1800 feet.

HORDERLEY AND MAY HILL ROCKS.—A series of sandstones, sandstone conglomerates, and silicious limestones, occurring in some of the border counties of England and Wales, have received this name. Their organic remains are chiefly corallines, but include *terebratula* and other shells, and are principally found in the limestone-beds. The thickness of this formation is estimated at about 2500 feet.

BUILTH AND LLANDEILO ROCKS.—This group, which, like the former, has been named from its most remarkable locality, consists chiefly of impure dark-coloured limestones, occurring in thin beds, together with a few sandstone and slaty strata. The organic remains are chiefly *Trilobites*, of which the species named *Asaphus Buchii* is most abundant and characteristic. This group is estimated at about 1200 feet in thickness.

GREYWACKE AND GREYWACKE SLATE.—The rocks termed greywacke are of rather an indefinite character: considered as a group, they present a series of sandstones, occasionally conglomerates, but more often fine-grained and slaty, and of slaty rocks of various kinds (termed greywacke slate), among which common roofing-slates are of frequent occurrence. Instratified with this series is the *greywacke limestone*, or *transition limestone*, which occurs in irregular bands, which are continuous for a greater or less extent. The series is still further complicated by frequently including beds and masses of *greenstone* and other trappean rocks. The sandstone and conglomerate beds may perhaps be described as occurring principally in the upper part of the series, (previously noticed as the Silurian rocks,) while the fine-grained slaty and altered rocks form the lowest portion of the group, and sometimes pass by insensible gradation into mineralogical clay-slate, which then forms in fact a portion of the present series. The colour of these rocks is generally a blueish gray, but sometimes brown, and occasionally red. They exhibit great regularity of cleavage.

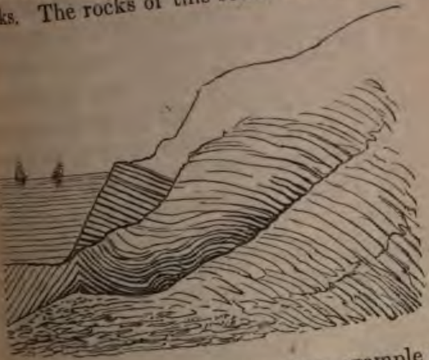
FOSSILS.—In this group of rocks fossils are much less abundant than in most of those which have been previously described. They are chiefly species of *producta*, *terebratula*, *spirifer*, and *orthoceratites*, but in descending through the series they become very rare, and in many of the lower slaty beds are but seldom, if ever, found.

LOCALITIES.—In many parts of Great Britain these rocks constitute very extensive and elevated tracts of country, and it may be said that there are few mountainous regions in any part of the world in which they do not occur in great abundance, showing that, at the period when these deposits were formed, there existed a general uniformity of action over a large portion of the earth's surface, an observation which applies very generally to the older series of rocks now coming under our consideration. The greywacke series occurs plentifully in Cornwall and Devonshire, and forms a large portion both of North and South Wales, where it constitutes many of the highest mountains and most beautiful scenery of the principality. The lake district of Westmoreland and Cumberland, so well known from its picturesque features, is principally formed of rocks of the greywacke series and protruded masses of granite. They form a large tract in the south of Scotland, and occur in the Isle of Man and in Ireland. On the Continent they are found abundantly in Germany, in the Alps, Norway, Sweden, and most other countries, as well as occupying extensive tracts in the mountains of America.

MINERAL PRODUCE.—The metalliferous contents of the greywacke group are very important, both in this and other countries. Most of the lead-mine districts of Wales are situated in these rocks, and also some of the mineral districts of Cornwall and Devonshire, producing copper, tin, lead, silver, manganese, and other metals. It produces in the Isle of Man, lead, containing a considerable proportion of silver, and includes some of the copper and lead mines of Westmoreland and Cumberland. Independently of metallic produce, these rocks are valuable for furnishing the slates used for roofing houses, which are very extensively quarried at Tintagel on the north coast of Cornwall, at Penrhyn and many other places in Wales and the north of England. They also furnish many of the softer hones used in sharpening cutlery.

The great mining districts of Cornwall are principally situated in a portion of the greywacke series, formerly considered as a primary clay-slate, and provincially termed "*killas*:" it there contains veins of tin and copper, of extraordinary richness and produce, and which have long constituted the principal wealth of the county. The metalliferous slate of Cornwall generally rests immediately upon granite, and it is chiefly at or near the junction of the two rocks that the principal mines are situated. This is the case with the great Consolidated Mines, the most extensive in the world, of which a section is given in Plate 4, the rich Tresavean Mine, the productive Carn Brea Mines, the well-known Dolcoath Mine, and many others. It may be observed that many of these mines are worked to a very great depth; the Consolidated Mines are about 300 fathoms, or 1800 feet, below the surface, being deeper than any other mine in Great Britain. The value of the copper ore raised in Cornwall amounts to nearly a million sterling yearly; and the value of the tin and other metals probably falls little short of half a million more.

ORIGIN.—The greywacke series may be considered as a marine deposit of particles, generally in a state of very minute subdivision, the lower portions of which have probably undergone much change of texture from their proximity to the subjacent pyrogenous rocks. The rocks of this series are often much con-



torted, of which an interesting example is given in fig. 7, which represents some cliffs upon the coast near Aberystwyth. Similar contortions occur very frequently in most of the rocks, which next require notice, especially gneiss and mica-slate. These contortions have been occasioned by the operation of those subterranean volcanic forces which produced faults and fissures in the harder and more consolidated rocks, but which, when acting upon soft and yielding matter, such as the slaty rocks must have originally been, have thus, as it were, *crumpled* them together. The thickness of this series can only be very roughly approximated, and of course varies much in different places: it certainly, however, amounts to several thousand feet.

TRANSITION LIMESTONE, OR GREYWACKE LIMESTONE.—This rock, as before noticed, forms a portion of the greywacke series, in which it often occurs in the form of large irregular beds. Its texture is compact and crystalline; the colours are extremely various, as black, brown, or reddish, and it is frequently veined and variegated with different tints. The organic remains are chiefly corals. This rock occurs plentifully in Devonshire, in the north of England, in various parts of the Continent, and in America. On account of its beautiful colours and variegated appearance it is much used for ornamental purposes, under the name of "*marble*," a term very generally applied to stones which will cut and take a polish, although very indefinite, from classing together substances which both geologically and mineralogically are very dissimilar. The most beautiful marbles of this class are brought from Spain and Italy, but some of great beauty are found in our own country, more especially at Babbicombe, and other places in Devonshire, where extensive quarries are opened. This marble is usually of a reddish colour, and is much used in the western counties for chimney-pieces and other ornamental purposes. The stupendous "Breakwater," at Plymouth, is built of a similar rock, which forms an immense bed or channel in the slate in the vicinity of that town, and is extensively quarried for various purposes. No general thickness can of course be assigned to this rock, but the beds are often locally several hundred feet thick.

PRIMARY ROCKS.

General views.—We have now arrived, in a descending series, at that obscure period of the earth's history, where we are guided by little or no analogy with existing circumstances. The primary rocks, which are next to be considered, contain no organic remains to point out the circumstances of their origin, no fragments of pre-existing rocks to indicate the materials from whence they were formed. Like the unstratified rocks, they consist of a few simple minerals in a state of crystalline aggregation, while they exhibit a mode of arrangement very similar, if not identical with, that of the stratified class, thus giving rise to great ambiguity as regards the manner in which they were formed. It has, however, been considered by Mr. Lyell and other geologists that they are nothing more than stratified rocks, altered in their texture by proximity to vast supporting masses of pyrogenous rocks; and in support of this opinion it may be said that the original elements of both classes are nearly the same, and that when trap rocks are intruded among the stratified class a similar change may be observed on a small scale. In these cases a partial fusion takes place, and a crystalline arrangement of particles, together with an obliteration of organic remains, are the result. Thus chalk and loose calcareous rocks become converted into compact crystalline limestone, and common sandstone is altered into a close-grained quartzose rock. In either case whatever fossils may have been contained disappear in the altered texture of the rock. This at least partial solution of a problem, which a few years since appeared to present difficulties almost insurmountable, must be considered as strongly marking the rapid advance of geological science.

We may now proceed to consider the individual character of this class of rocks, which will not, however, require any very lengthened notice, as they do not occupy very extensive tracts in this country, where they are not developed on so extensive a scale as on the Continent, or in America.

Primary Sandstone.—This rock is chiefly composed of quartz, having a compact and granular texture, and sometimes containing a small proportion of other mineral substances imbedded. It occurs in Scotland, and forms large tracts in the Andes and Brazil: it there contains native gold in small particles, cinnabar, specular iron, and sulphur. Some of the gold-mines of Brazil are situated in loose ferruginous beds, which appear to have resulted from the ruin of this sandstone, and some of the beds contain platina, palladium, and diamonds.

Primary limestone.—This rock is sometimes a pure carbonate of lime, but often contains a variety of accidental ingredients, as quartz, mica, and hornblende, crystallized throughout the mass. The texture is compact and crystalline, or finely granular; some varieties indeed are called "*saccharine*," from their extreme resemblance to white sugar. This rock is found in Scotland, the Hebrides, in the Alps, the Pyrenees, and the mountains of America.

Some of the fine white varieties of primary limestone are well known from their uses in the arts, as "*statuary marbles*." The famous "*Parian marble*" of the ancients, with some other kinds much prized by them, were found in the Grecian archipelago. The celebrated "*Carrara marble*," which is now chiefly used by sculptors, is brought from Italy. Similar varieties, well adapted for statuary purposes, are found in many other parts of Europe. This rock contains no metallic ores of importance; it does not occupy large tracts, but occurs in beds among primary rocks, generally clay-slate, or gneiss.

PRIMARY CLAY-SLATE.—This rock considerably resembles some of the finer varieties of greywacke slate. It is composed of silica, alumina and oxide of iron, with other substances in small proportion. Its texture, as the name implies, is slaty and regularly jointed, and it generally separates into pieces of a rhomboidal form, having a silky appearance, parallel to the thin laminæ of which it is composed, but a dull earthy cross fracture. It is often unctuous to the touch, and of a grayish, bluish, or brownish colour, sometimes nearly black. This rock (mineralogically) is widely distributed; it is found in the mining districts of Cornwall, in Scotland, in many parts of the Continent, and America: but from recent discoveries the term primary is no longer applicable in many cases. Although occasionally used both as a building-material and roofing slate, the quality is much inferior to many other kinds of stone. This rock is, however, of great importance from the mineral wealth which, in common with most others of the primary class, is often included in it.

Clay-slate is metalliferous in Cornwall, in Ireland, in many parts of the Continent, and in America, where the *Valenciana*, formerly the richest of the Mexican silver-mines, is partly situated in this formation.

MICA SLATE.—The texture of this rock, as its name implies, is slaty, and mica is the characteristic ingredient, being generally accompanied only by quartz. *Garnets* occur in this rock very plentifully, sometimes even forming one of its constituents; the most usual composition, however, is mica, or mica and quartz in thin parallel layers. Mica-slate occurs but sparingly in this country, having been chiefly noticed in some of the mountains of Scotland, where it occupies rather extensive tracts, and also in some parts of Ireland; it is, however, very abundant in many parts of Europe, and also in America. It contains gold, and some of the metallic ores, as silver, lead, zinc, and antimony.

GNEISS.—The composition of gneiss does not essentially differ from that of granite already described, the principal distinction between them being, that in gneiss the mica is generally disposed in parallel planes, so as to give the rock a slaty texture, while in granite it is equally disseminated throughout the mass. Gneiss can scarcely be said to occur in England, but is abundant in Scotland, and many other parts of the world, and generally forms elevated tracts on the borders of granite mountains. Some of the mining districts of Germany are situated in this formation, which furnishes silver and most other metals in considerable abundance. The observations of Professor Phillips have lately thrown much light upon the origin of gneiss; he has shown that the constituent minerals, instead of being truly crystallized *externally*, as in granite and syenite, are in reality slightly rounded by attrition, and that gneiss must therefore be regarded as a derivative rock.

UNSTRATIFIED ROCKS.

GENERAL VIEWS.—The unstratified class of rocks will not require a very long notice, both on account of the general similarity of their composition, and because, although most of them occur abundantly in Great Britain, the tracts they occupy are much less extensive and important than those constituted by the stratified class previously described.

The elementary principles of these rocks are chiefly *silica* and *alumina*, (the bases of *sand* and *clay*,) combined with the alkalies, *potash* and *soda* in small proportion, and very generally with *iron* in a state of oxidation. The immediate constituents are quartz, felspar, mica, hornblende, augite, olivine, &c. The differences we observe in them, however great, are therefore in many cases rather the result of modifying circumstances which may have attended their original formation, than any specific difference in the rock itself. To explain the cause of a great variety of rocks resulting from nearly the same principles, we must advert to their igneous origin, remarking that the same mineral substance, cooling under different circumstances, will assume a totally different aspect. Thus a mass of fused matter, when allowed to cool very rapidly, forms a substance of a glassy nature; when the cooling is very slow, a stony and crystalline arrangement of particles will be occasioned; while intermediate rates produce a variety of different results, each producing, from the same original substance, a product having a very different texture and appearance.

If we apply this well-authenticated principle, the result of actual experiment, to the unstratified rocks, we shall at once perceive how so much variety has arisen from the same elementary substances, produced, as they have been, under every possible variety of local circumstances, both during the present state and former revolutions of the globe. It will also explain a fact which adds much to the complexity of this branch of geological science, or the *gradual passage of one kind of rock into another*, which often causes a variety of nice mineralogical distinctions, even in different parts of the same mass.

If we compare modern volcanic rocks with basalt and other trappean formations, nearly resembling them in composition, one of the principal differences will be in the greater compactness of the latter. This difference, however, is easily explained, for it is certain that these rocks were mostly formed while our continents were yet the bed of the ocean, and they must therefore have cooled under an immense superincumbent pressure of water, while the interior of a mass of lava, from a similar cause (or the pressure surrounding it), is much more compact than the external portion.

MODERN VOLCANIC ROCKS.—These of course are not found in Great Britain, although abundant in the neighbourhood both of active and extinct volcanoes, as in France, Germany, Italy, Sicily, the Azores, and in the great chain of the Andes, which presents no less than one hundred volcanic summits. *Lava* is generally the most abundant; it is of brownish or grayish colour, and a porous cellular texture, owing to the quantity of gaseous matter which it contains when first ejected from the volcano, and which escapes while the mass is cooling. *Pumice* is a volcanic product which very frequently accompanies lava.

BASALT.—This rock is generally of a black colour, and of a fine crystalline texture; it occurs in irregular beds, in dykes or channels, and in large *overlying* masses, so termed because uncovered by other rocks. (See trap rocks, Plate 2, fig. 1.) Basalt often presents a *columnar structure*, and occasionally forms one of the most remarkable of all natural phenomena, or an arrangement of these columnar masses in rows placed upon one another, and rather resembling vast architectural piles than the work of nature. The two most remarkable instances of this phenomenon in the world are within the limits of the British Islands, being Fingal's Cave in the Isle of Staffa, and the Giant's Causeway in the county of Antrim, on the north coast of Ireland.

FINGAL'S CAVE.—Fingal's Cave consists of a magnificent vault or archway, surrounded on each side by regular piles of basaltic columns, and surmounted by a massive natural roof. The entrance is open to the sea, and the cavern extends inwards 230 feet in a straight direction, being forty or fifty feet in width, and about seventy in height, presenting much the appearance of the aisle of one of our ancient Gothic churches or cathedrals. To this resemblance à beautiful allusion has been made by Walter Scott, in the 'Lord of the Isles,' when describing the scenery of Staffa.

"——— that wondrous dome,
Where, as to shame the temples deck'd
By skill of earthly architect,
Nature herself, it seem'd would raise
A minster to her Maker's praise;
Not for a meaner use ascend
Her columns, or her arches bend;
Nor of a theme less solemn tells
That mighty surge that ebbs and swells."

Giant's Causeway.—The Giant's Causeway is probably the most magnificent specimen of nature's architecture existing in the world, and is on a far more extensive scale than the Isle of Staffa, although it wants the beautiful cavern of the latter. It consists, as the name well expresses, of several immense terraces, rising from the coast, one above another, which are principally composed of vast basaltic columns, having altogether some resemblance to those stupendous piles of ancient architecture which form so striking a feature in Martin's gorgeous pictures.

Basalt is chiefly found in the coal-districts of this country; its occurrence at Dudley in Staffordshire has been already noticed, and in the coal-mines of the north of England it is frequently met with, and termed by the miners "*whinstone*." Basalt forms many of the picturesque and "castled crags" of Scotland, and occurs abundantly in Germany and most other countries.

AMYGDALOID.—A rock called amygdaloid is nearly allied to basalt; its appearance is cellular and porous like that of lava, but these cells are filled up by small nodules of mineral substance, generally calcareous spar, which have been carried in by infiltration. These nodules are of a whitish colour, and have sometimes the appearance of almonds, whence the name (synonymous with *almond-stone*) has been derived. Occasionally the imbedded minerals have become decomposed and fallen out; the rock has then much the appearance of a porous lava. Amygdaloid occurs in Derbyshire, interstratified with the carboniferous limestone, and forming three beds of great thickness and extent, which separate the limestone into four divisions. It is there provincially termed "*toad-stone*," a name occasioned no doubt by its dark brown colour and spotted appearance. Amygdaloid occurs abundantly in Germany and in most countries where unstratified rocks prevail.

GREENSTONE.—This rock is generally composed of hornblende and felspar, intimately blended together, and, as its name implies, the colour is green, generally of a very deep tint. Greenstone becomes *porphyritic*, from containing crystals of felspar; other varieties are *slaty*, and are therefore termed *greenstone slate*, or, when composed chiefly of hornblende, *hornblende slate*. These rocks occur principally among primary formations, either in the form of dykes, interstratified, or protruded and overlying masses. They are abundant among the slates of Cornwall and Devonshire, among those of North Wales, the north of England, and the large primary tracts of Scotland. Their foreign localities are too numerous to be mentioned, but they occur associated with the older slates in most mountainous countries.

SYENITE.—This rock is generally a crystalline aggregate of felspar and hornblende, the former being the principal ingredient, and of reddish colour. Quartz and mica sometimes occur in it, and it then closely resembles granite, of which it may indeed be considered as merely a more modern variety. Syenite occurs in Charnwood Forest, in Leicestershire, in the Malvern Hills, and other parts of Great Britain. It is abundant in Hungary, where, with its associated porphyritic rocks, it affords gold, silver, and other metals: it occurs also in Upper Egypt, where rocks of this class were extensively quarried by the ancients, forming the material of many of their colossal statues and sarcophagi, as may be seen in the fine specimens preserved in the British Museum. It is found in America and most other parts of the world.

PORPHYRY.—This denomination must be considered as a generic appellation, including many rocks, differing much in composition, but agreeing in this, that they consist of a basis, or *paste*, of some homogeneous mineral substance, in which certain other mineral substances are imbedded, usually in small crystals, thus giving the rock a variegated or spotted ppearance. The basis is usually *hornblende*, or *compact felspar*, or minerals having a glassy or vitreous texture, as *pitchstone* and *obsidian*, the substances imbedded being generally either *quartz* or *felspar*, especially the latter. Porphyritic rocks occur in Cornwall, forming either highly-inclined beds or irregular masses in the slates of that and the adjoining county, where they are termed "*elvan courses*" by the miners. (See Plate 5) Porphyritic rocks occur abundantly on the Continent, in America, where they form a large portion of the Cordilleras of Mexico, and are found in most parts of the world. Porphyries and syenites are sometimes capable of receiving a fine polish, when they present a very beautiful appearance, owing to their peculiar colours (chiefly shades of red) and variegated appearance. They are sometimes used, therefore, for ornamental purposes, but never to any great extent, on account of their extreme hardness, and the consequent difficulty and expense of cutting and polishing. Notwithstanding this, as before noticed, they were largely used by the ancients, more especially by the Egyptians.

DIALLAGE ROCK.—This rock is composed of *diallage* (a mineral consisting of silica combined with alumina, magnesia, &c.) and of *felspar*. It has a granular and variegated appearance, green being the prevailing colour. It is generally associated with hornblende rock or serpentine, and is considered to be merely a variety of the latter.

SERPENTINE.—This rock is composed of *silica* and *magnesia*, in nearly equal proportions, but combined with *alumina* and *oxide of iron*. The colour is generally various shades of green or brown, often intermixed with red, and, from its somewhat resembling the appearance of a serpent's skin, the name has been derived. The texture is compact but not crystalline, and the rock has sometimes a *soapy* feel, owing to the magnesia it contains. It occurs in Cornwall, forming the well-known Lizard district, in Scotland on the coast of Banffshire, and in many other parts of the world. The variety called noble serpentine is much prized for its beauty and the fine polish it is capable of receiving. The rock called "*verd antique*" is valued for the same reason; it is a conglomerate of limestone and serpentine, and is found in Italy. Serpentine does not appear to furnish any mineral contents of importance, and the districts formed by it are generally very barren, as is usually the case with rocks containing a large proportion of magnesia. This rock sometimes contains magnetic iron ore in such quantity that the needle is affected in its vicinity. The Mona marble belongs to this class.

GRANITE.—This rock, as before noticed, is composed of *felspar*, *quartz*, and *mica*, the felspar being usually most, and the mica least, abundant: these minerals are in a crystalline state, and compactly aggregated together. Granite was formerly considered to be the fundamental rock of the globe, on which all others rested; but, although some granites possess a very high degree of antiquity, it is certain that others have been formed at a much more recent period, in some cases even posterior to the fossilliferous and stratified rocks, on which they are sometimes found to rest, having been protruded among them in the same manner as basalt and other modern pyrogenous rocks. Granite of the oldest formation is, however, certainly one of the lowest rocks composing the interior of the globe which is exposed to human observation. When seen rising through the other strata it generally forms lofty and rugged chains of mountains, which, when viewed on the large scale, have a tendency to form vast troughs or basins, in which the newer strata have been deposited. In these chains, however, the granite is by no means continuous; it appears here and there in the shape of vast irregular masses and mountain-peaks, the intervening eminences being generally composed of superincumbent primary rocks, as gneiss, mica-slate, and clay-slate, into which the granite protrudes itself in veins and irregular masses, of which many fine examples may be seen in Cornwall.

Localities.—Granite is a very abundant rock in the south-western parts of England, where it forms the bold promontory called the "*Land's End*," and, rising through the superincumbent slates, forms a series of barren elevated tracts, running nearly east and west through Cornwall, and constituting around their borders the principal mining districts of that county. The same granite range reappears at Dartmoor in Devonshire, where it forms a large and elevated tract, rising in some points nearly 1800 feet above the level of the sea. Some portions of this mass, together with the superincumbent slates, are very metalliferous, chiefly producing tin and copper. It will be seen by Plate 4 that the Consolidated Mines are situated at the junction of these rocks, which is the case with many of the most productive mines in Cornwall. Granite occurs also in the north of England, and very abundantly in Scotland and Ireland. It forms some of the elevated peaks of the Alps, of the Himalaya mountains to the north of India, and may be said to occur in mountainous situations in most parts of the world, although very frequently overlaid and partially concealed by other rocks, as gneiss and mica-slate.*

Granite districts are usually wild and barren, owing to the materials of this rock being principally silicious and resisting decomposition, and also from the height and bleakness of their situation being unfavourable to cultivation. It is sometimes, however, found in a soft decomposed state, owing to the disintegration of the felspar; of this there are many examples in Cornwall. Granite is called *porphyritic* when the felspar is very predominant and in large crystals, as near the Land's End, and in many other parts of Cornwall and Devonshire.

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* Although granitic rocks do not exist *in situ* within a very considerable distance of London, or indeed the south-eastern part of England generally, it is not difficult to obtain sight of very characteristic specimens within the limits of the metropolis, and from these the mere composition of the rock may be studied almost as well as by an examination of the quarries whence the stones were obtained. The common paving-stone used for paving the carriage-ways is the Aberdeen granite; it is close-grained and compact, of a grayish tint, or sometimes slightly tinged with red or purple; good specimens of the stone may be seen wherever new pavement is being laid down. Waterloo Bridge exhibits both the Scotch and the West of England granite, and well illustrates the difference of their texture. The coping-stones of the balustrades are composed of the latter, a coarse yellowish granite, in which the felspar and mica are in very distinct crystals, while the balustrades themselves are formed of the former, a compact and small-grained granite. A good specimen of porphyritic granite may also be seen in the obelisk lately erected at the end of Fleet-street.

USES.—The uses of granite as a building-material are well known, although it is only of late years that it has been applied extensively to that purpose in the metropolis. The facing or exterior of London Bridge and of Waterloo Bridge is granite, partly from Cornwall and partly from Scotland, and many fine varieties of this rock may be seen in these magnificent structures. The reddish and coarse-grained masses, it may be observed, are from Cornwall, the darker and fine-grained pieces chiefly from Aberdeen. Within the last few years most of the principal thoroughfares in London have been paved with granite, and its extreme durability renders it deserving of adoption in all public works, although too costly for common purposes.

When in a decomposed state, granite forms a valuable material in the manufacture of porcelain and china ware. For this purpose the disintegrated felspar is carefully separated by washing from the other constituents of the rock, and collected in the form of an exceedingly fine white powder. Large quantities are thus obtained in some parts of Cornwall, especially near St. Austell, and are shipped from the adjoining ports to the districts where the article is manufactured.

MINERAL PRODUCE.—The ores of a great number of metals are situated in granite, many of the most productive tin and copper veins in Cornwall being, as before noticed, worked in, or immediately adjoining, this rock. Tin, however, is the metal most abundantly found in it, usually in veins, but often disseminated throughout the mass of the rock, which is the case at the celebrated Carclaze mine. Granite is also metalliferous in many other countries, although perhaps less so than some of the primary rocks previously described, which may be considered as forming, in all parts of the world, the principal depositaries of the metallic ores.

In districts formed by the unstratified series of rocks, thermal and mineral springs, having an obvious connexion with them, are by no means uncommon. They have been observed in Germany, in the Alps, the Pyrenees, on the borders of the Himalaya mountains, and many similar situations. Water for domestic purposes is generally found in the superficial deposits resting upon these rocks, and when it rises from the rocks themselves it may generally be attributed either to the occurrence of faults, or of soft decomposing channels which occasionally traverse them. In sinking deep wells or boring for water (although the latter must be considered very precarious), attention should always, therefore, be paid to the above circumstances, as upon them the success of the operation may in great measure depend.

The nature and position of the metalliferous deposits of this country have been already incidentally noticed, in describing the various rocks and formations in which they are contained. With a desire of still further illustrating this important subject, the tabular statement appended to this work has been drawn up, and to this the reader is referred for a general view of the geographical distribution, and of the present estimated amount and value of our mineral and metallic produce.

PART IV.

PRACTICAL APPLICATIONS OF GEOLOGY.

APPLICATION TO MINING: General Remarks—Miners necessarily good local Geologists—Mistaken Views of the Science—Its real Value to the Miner—General Laws which Geology has discovered relative to the Distribution of Metalliferous Masses—Application of Geology to Coal-mining—Abortive Trials for Coal in the Oolites—Abortive Trials for Coal in Ireland—Ascertained Extension of our Coal-fields owing to Geological Science. APPLICATION OF GEOLOGY TO ENGINEERING: General Remarks—Foundations for Roads, Railways, &c.—Slopes and Embankments—Care required in their Formation—Frequent Failures—Rules for their Formation—Artesian Wells. APPLICATION OF GEOLOGY TO ARCHITECTURE: General Remarks—Building Materials—Stratified Rocks—Calcareous Freestones—Mode of Decay and Principles of Selection—Choice of Materials unnecessarily limited—British Marbles—Unstratified Rocks considered as Building Materials—Granite, Syenite, &c.—Foundations of Buildings—Concluding Observations. ON THE STUDY OF GEOLOGY AND UTILITY OF GEOLOGICAL MAPS AND SECTIONS: Preliminary Knowledge—Localities requiring Examination—Most simple Modes of acquiring Knowledge—Geological Maps—Geological Sections—Conclusion.

APPLICATION TO MINING.

GENERAL REMARKS.—A minute detail of all the various useful applications of which the science of geology is in its present improved state susceptible, would of itself occupy a volume, and many of these will no doubt have occurred to the reader's mind in perusing the foregoing pages, their nature varying according to the peculiar pursuits in which he may be engaged, or the views with which his attention may have been directed to the study. It unfortunately happens, however, that practical men are too apt to disregard the advantages of scientific knowledge as bearing on their own pursuits, and thus many of the benefits which this study ought to confer are often sacrificed to absurd and unfounded prejudices. There are probably few sciences, the knowledge of which, in a limited form, is more widely diffused than that of geology; its local and isolated facts are known —often perfectly and accurately known to many, more especially the miner and engineer, whose pursuits naturally lead them to an acquaintance with the nature and distribution of the great mineral masses constituting the exterior of the globe. Even the most casual observer, as was shown in the former part of this volume, must be well acquainted with many of those striking facts on which geology is founded, although ignorant of their connexion and importance. To give consistency to the scattered elements of knowledge thus incidentally acquired, to show the mode in which they are generalized into an orderly and beautiful scientific arrangement, has been the prominent object of these pages, and no opportunity has been lost of pointing out the readiest modes of acquiring further information on these subjects.

MINERS NECESSARILY GOOD LOCAL GEOLOGISTS.—The knowledge of the miner as regards the most difficult and anxious part of his profession—forming a correct judgment on the indications presented by nature of the existence of mineral wealth buried deep below in the solid strata of the globe, and de-obtain, it must not, however, be supposed that these are the only ones which the science can bestow, or that many cases may not happen in practice in which the utility of geological knowledge will be directly and forcibly experienced. In our older mining districts, which have been so completely honey-combed by the labours of succeeding generations, that to the skilful miner the rocks and minerals are almost as well known as if they could be made transparent; this will indeed but rarely happen, yet the expense of mining operations is there so great, and the works of such magnitude, that even the chance, small as it is, of immediate and direct assistance from science, ought not by any means to be disregarded. In mineral districts which are less thoroughly explored, the light of science is of the greatest value, since it not only shows the rocks in which mineral wealth is most likely to be contained, but also those particular portions of them where the greatest degree of enrichment may be expected. The great laws which regulate the distribution of mineral veins, and even the general laws which indicate the arrangement of their subterranean treasures, are now clearly and thoroughly established, although the minor ones, which seem capriciously to determine the metallic ores into small and confined localities, are still unknown, and patient research can alone determine the fact.

GENERAL LAWS WHICH GEOLOGY HAS DISCOVERED, RELATIVE TO THE DISTRIBUTION OF METALLIFEROUS MASSES.—These important laws, which are of the highest value to the mining engineer, and which will in future exercise an important influence upon all extensive mining operations, are entirely geological generalizations, and the establishment of them may be triumphantly appealed to, as among the many direct benefits which have arisen from the cultivation of geological science. It is true that the local and isolated facts upon which they are founded have long been known to the practical miner, but the generalization of these facts into ascertained laws, and the connexion of them with known natural principles, in fact those circumstances from which their chief value is derived, has resulted entirely from the labours of geologists.

It has long been known in Cornwall that the metalliferous veins or "lodes" are chiefly productive of the metallic ores in those situations where the granite and superincumbent slaty rocks are in contact, of which an excellent example is afforded by the Consolidated Mines, as will be seen in the section at the end of this volume; but the geologist has discovered that is only one case of a very extensive range of phenomena, and that the whole are subject to a general law, which very probably regulates the entire enrichment and productiveness of mineral veins—the proximity of pyrogenous and sedimentary rocks, and and the changes thus superinduced upon the latter. In this manner certainty and precision have been given to a knowledge which was before only vague and partial.

It has long been known that metalliferous veins are most productive where they are intersected by those generally barren dykes of mineral substance which are commonly termed cross-veins or "cross-courses," but the geologist has shown that these dykes are themselves produced by, or connected with, subjacent masses of pyrogenous rocks, and, therefore, that the one phenomenon is included in the other. He has also traced with an accuracy which, excepting for this science, would never have been attained, the position and configuration of the pyrogenous masses, by which such important effects have been occasioned; he has shown the extent of the metamorphic rocks produced by their action, and pointed out the general range and peculiarities of the faults and dislocations of the sedimentary rocks produced by them. The application of these facts and principles, and their great value to mining, when pursued on an extensive scale, and more especially in new mineral districts, must be well known to the mining engineer, and can hardly require to be pointed out at greater length.

APPLICATION OF GEOLOGY TO COAL-MINING.—In the preceding remarks on the application of geology, reference has only been made to that particular branch of mining which has for its object the extraction of minerals found in veins, as tin, copper, and lead; if, however, we turn to that important department of the art which is directed to coal and iron—minerals, of which this country may be estimated to produce an annual value of fifteen or sixteen millions sterling, its utility will be still more striking. The reader who has attentively perused the foregoing pages cannot fail to have observed that these invaluable minerals are always found associated together in a particular series of rocks, now clearly defined by geologists, and that good workable coal is never met with in this country in any other formation.

ABORTIVE TRIALS FOR COAL IN THE OOLITES.—Had it not been for the progress of geological science, and the indefatigable zeal, labour, and talents of geologists, this most important truth, now so clearly established and so universally acknowledged, would merely have existed as a dim perception in the minds of some few sagacious individuals, and the actual benefits arising from it would never in any sensible degree have been experienced. The abortive trials for coal in the lias, and the popular errors of supposing it to exist in rocks situated at a great interval above the true coal-measures, have already been noticed, and it would be easy to furnish a long list of unsuccessful undertakings founded upon such erroneous ideas. Upon trials of this kind, hundreds of thousands of pounds must have been expended in works which geology has shown to be entirely fruitless, and which it will in future prevent from being undertaken.

ABORTIVE TRIALS FOR COAL IN IRELAND.—The fruitless and absurd trials for coal which have been made in England appear to have been entirely confined to formations lying *above* the coal-measures; in Ireland, on the contrary, a country where coal is perhaps more abundant in proportion to its size than in any other, similar abortive trials have been chiefly carried on in rocks *below* the coal. On this subject the remarks of a deservedly high authority, Mr. Griffith, are well deserving of attention. In his valuable survey of the Connaught coal-district, that gentleman observes, "It may be useful to give a brief sketch of the geological position of that district, with respect to the neighbouring country, and to suggest to landed proprietors the kind of mines, or other valuable mineral substance, which is likely to be found in the different species of rocks that occur in the country. It is time that it should be known that no coal is likely to be met with in the greywacke or limestone district in the north-west of Ireland, and that we should no longer hear of and witness useless trials for coal being commenced and persevered in, at the instigation of ignorant or designing miners. There is no real scarcity of coal in Ireland, but, unfortunately, more money has been fruitlessly expended in searching for coal, where none was likely to be found, than in those situations where, if sought for with judgment, there is little doubt of its being discovered." The truth and justice of the remarks here quoted can require no comment, as they must at once carry conviction to the mind.

A good example has already been given in these pages of the little value which can be attached to the opinions of merely practical men on the geological indications of coal; a further illustration may here be added from the authority above quoted.

"Many fruitless trials have been made in search of coal in different parts of the calp * country, by ignorant miners, who mistook the black slate-clay with which it is interstratified for the slate-clay which forms a principal member in the coal series."

The sketches of our different coal-fields, which have been given in the body of this work, are quite sufficient to show the great advantage which must be derived in working coal from the general and corrected views which geology has given of the order and stratification of the great coal-districts, and the range and extent of the beds composing them, as well as the faults by which they are dislocated.

ASCERTAINED EXTENSION OF OUR COAL-FIELDS, OWING TO GEOLOGICAL SCIENCE.—On another important circumstance, the prolongation of our coal-fields below the magnesian limestone and the new red sandstone, geology has thrown a great and valuable light, which could not otherwise have been obtained. Large districts, exhibiting no external appearance of coal, may now be calculated upon for supplying our consumption when the present mines shall begin to fail; and in many cases these may almost be looked upon as the gift of geological science. It is true that, independently of geology, a dim and limited perception of many of these facts would have existed in the minds of a few intelligent practical individuals, but it would have been, like the premature dawning of many great discoveries, of little

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* "Calp" is the name given in Ireland to the lower impure beds of carboniferous limestone, which often contain beds of shale interstratified with them.

value to mankind, had it not been stamped with the generalization, the certainty, and precision of science. Although it would be easy to multiply examples, and to extend remarks on the subject before us, enough has now been said to prove that the applications of geology to mining are both numerous and important.

APPLICATION OF GEOLOGY TO ENGINEERING.

General remarks.—If we now turn to engineering, the applications of geology to that profession, as will at once be seen, are exceedingly numerous, and of so obvious a nature as scarcely to require comment. No engineering work of any magnitude can be undertaken in which either excavations or embankments, or perhaps both, are not necessary, and these operations generally constitute one of the most formidable items of expense, and one entirely dependent on local circumstances, which, without some geological knowledge, can never be properly appreciated or understood. The material to be removed may be valuable, or it may be worthless, or it may be a compound of both; it may be worked by simple means, and at a small expense, or it may require blasting, and present great difficulties in excavation, and consequently occasion great expense. It is also possible that, by deviating a little from the original plan, or by selecting a better locality, the above circumstances may be greatly modified, or even entirely changed. In tunnelling, deep cutting, making docks, and many other works, it is obviously of the first importance that all these circumstances should be thoroughly considered; and in laying out lines of railway, roads, and canals, they must form a very important element of calculation; yet, without some geological knowledge, it is obviously impossible correctly to appreciate them.

To enter at any length upon the applications of geological science to engineering purposes, would greatly exceed our limits, and indeed is hardly necessary, as these applications can scarcely fail to have suggested themselves to the reader who has perused the foregoing pages. The following passages from a well-known and standard work—Sir Henry Parnell's treatise on roads—are, however, so much to the purpose, and convey so much useful information on the subject under consideration, that the author is induced to extract them, as forming an admirable illustration of the principles which have been laid down.

The following remarks apply equally to the laying out and construction of railways and common roads.

FOUNDATIONS FOR ROADS, RAILWAYS, &c.—"To comprehend thoroughly the great importance of making a regular and strong foundation, it should be borne in mind that roads are structures that have to sustain great weights and violent percussion; the same rules ought, therefore, to be followed with them as are followed with regard to other structures.

"In building edifices which are to support great weights, whether a church, a house, or a bridge, the primary and indispensable consideration of the architect is to obtain a permanently firm and stable foundation.

" He well knows that, unless this be first substantantially made, no future dependence can be placed on the stability of the intended superstructure; but this circumstance, which most requires precaution, has but recently been attended to in the formation of roads, and only on those roads in Scotland, and between London and Holyhead, which have been under the direction of Mr. Telford.

" If the foundation of a road be not sufficient and equal to the pressure it has to sustain, the whole fabric, though in other respects ever so well constructed, must fail in permanent stability, and its hardness will be imperfect on account of its elasticity."

SLOPES AND EMBANKMENTS.—The formation of slopes and embankments is a subject which requires much attention on the part of the engineer, nor can any general rules be laid down which do not require modification from merely local circumstances. When deep cuttings are bounded by slopes of very gradual inclination, the waste of land is very great, and the injury often done to valuable property is immense, circumstances equally productive of opposition from landowners, of trouble to the engineers, and expense to the proprietors of the works. On the other hand, slopes which are formed at too high an angle of inclination, and without due attention both to the nature and local circumstances of the stratification, are liable to continual slips, and are a source of endless expense and trouble. Sir Henry Parnell's remarks on the subject are highly deserving of attention:—

CARE REQUIRED IN THEIR FORMATION.—He observes, "Great care is necessary in making high embankments: no person should be intrusted with these works who has not had considerable experience as a canal or road maker, for, if the base of an embankment is not formed at first to its full breadth, and if the earth is not laid on in regular layers or courses not exceeding four feet in thickness, it is almost certain to slip."

FREQUENT FAILURES.—"There have been but few attempts to make embankments by turnpike trustees that do not afford illustrations of this defect, and of a want of knowledge of the proper rules by which these works should be managed. No doubt a chief reason for making cuttings and embankments, as is frequently the case, with slopes of one to one, has been to save expense in the purchase of land and moving earth; but the consequence of making such slopes is, that the earth is constantly slipping, so that, in the end, the expense is always greater in correcting the original error than it would have been had proper slopes been made in the first instance."

RULES FOR THEIR FORMATION.—"The slopes at which cuttings and embankments can be safely made depend entirely upon the nature of the soil. In the London and plastic clay formations it will not be safe to make the slopes of embankments or cuttings that exceed four feet in height with a steeper slope than three feet horizontal for one foot perpendicular.

"In cuttings in chalk or chalk-marl the slopes will stand at one to one. In sandstone, if it be solid, hard, and uniform, the slopes will stand at a quarter to one, or nearly perpendicular.

"If a sandstone stratum alternates with one of clay or marl, it is difficult to say at what rate of inclination the slopes will stand; this will in fact depend upon the inclination of the strata. If the line of the road is parallel to the line of the bearing of the strata, in such cases large masses of the stone become detached, and slip down over the smooth and glassy surface of the subjacent bed. There are many instances of slips in sandstone and marl strata, under such circumstances as those now described, where the slopes are as much as four to one. If the road is across such strata, or at right angles to the line of bearing, then the slopes may be made one and a half to one; but if the strata are horizontal, even should there be thin layers of marl between the beds of stone, the slopes will stand at a quarter to one. But it will be necessary, if the beds of marl exceed twelve inches in thickness, to face them with stone. In the Oxford clay, which covers so great a portion of the midland counties of England, the slopes should not be less in any instance than two to one, and even in some parts of this formation they should be made three to one if the cuttings are deep. In all such cases, if any beds of gravel or sand are found intermixed with the clay, drains should be cut along the top and even in the sides of the cuttings; for, if this precaution be not taken, the water which will find its way into the gravel will, by its hydrostatic pressure, force the body of clay down before it, and slips will take place even when the inclinations are as much as four to one; and when this occurs it is extremely difficult to re-establish them.

"In limestone strata, if solid, slopes will stand at a quarter to one; but in most cases limestone is found mixed with clay beds, and in such cases the slopes should be one and a half or two to one. In the primitive strata, such as granite, slate, or gneiss, slopes will stand at a quarter to one. Before quitting this subject it is proper to remark that in every instance of deep cutting the greatest pains should be bestowed in examining the character of the material to be removed, as much difficulty will be avoided by proceeding this way."

ARTESIAN WELLS.—The application of geology to Artesian wells, and indeed to all extensive trials for water, is almost too obvious to require remark. The depth and abundance of springs, the quality of the water, and its ascending power, depend entirely upon geological causes, and can only be estimated with any correctness by the practical geologist. Some local situations are highly favourable to the formation of Artesian wells; in others, on the contrary, there is scarcely a probability of success; in some places a small depth will be sufficient to obtain water, in others the depth must be very considerable; and these are questions which can be decided by geology alone. It would be easy to enumerate many cases of failure and great pecuniary loss in works of this kind, merely from neglecting these obvious precautions, and a due examination of the spot by competent persons, previous to their commencement.

APPLICATION OF GEOLOGY TO ARCHITECTURE.

General remarks.—The value of a limited acquaintance both with minerology and geology to the architect and builder must be readily apparent, as without it they may often err both in the choice of materials and the laying out of foundations for buildings—certainly the two most important points which require their consideration. As regards the first of these, the choice of materials, it is lamentable to observe the ignorance or inattention which has so often prevailed, and the consequent premature decay of many of our finest national structures, and this too in a country which affords an inexhaustible variety of stone of the finest and most durable quality. It is hardly going too far to say that, of the architectural materials afforded by Great Britain, the very worst and most perishable have hitherto been chiefly made use of. It is much to be hoped that a similar misdirected choice may not in future be made, and the best security against it will be found in a more general acquaintance with the nature and distribution of those natural storehouses whence the materials of architecture are derived.

BUILDING MATERIALS.—Referring to the great classification of rocks into *stratified* and *unstratified*, the architectural quality of the stone afforded by each is so strongly marked, that we cannot do better than to consider them under these heads.

STRATIFIED ROCKS—CALCAREOUS FREESTONES.—The stratified rocks afford a great variety of architectural materials, all sandstones, freestones, limestones, and marbles, belonging to this class. The above stones are valuable as being soft and easily worked, and the last named, in consequence of readily receiving a polish, and being admirably adapted for ornamental purposes; some, however, are far more durable than others, and much judgment is required in their selection. Sandstones, freestones, and some kinds of limestone, are chiefly obtained for architectural purposes from rocks of the oolitic series, more especially the Bath stone and Portland stone, and, where great durability is not required, are undoubtedly very excellent building-materials; but all rocks of this class, from their loose earthy nature, soon yield to the ravages of time. For bridges, especially, they ought never to be used, and the constant and expensive repairs required by Westminster and Blackfriars Bridges sufficiently prove the folly of employing them in works of this kind.

MODE OF DECAY AND PRINCIPLES OF SELECTION.—As rain-water is the first and most active agent in destroying the exterior of buildings, by percolating through the pores of the stone, often, perhaps, acting chemically upon it, and always, especially during winter-time, mechanically also, (the expansion produced by freezing completely disintegrating the surface,) the value of building-stone may in some measure be estimated by the quantity of water which it absorbs, that which imbibes it very freely being of the least value, and *vice versâ*. As the texture of sandstones and freestones varies greatly in different localities, both from the nature of the cementing principle, and from being more or less earthy or compact, great attention should always be paid to the selection of those which are both strongest in their nature and least pervious to water.

CHOICE OF MATERIALS UNNECESSARILY LIMITED.—It is probable that custom has limited the attention of the architect too exclusively to the oolitic series of rocks, and that in the older secondary strata lying below it, in which a greater degree of induration very generally prevails, many stones of a similar character, but harder and more durable, might on proper examination be found. The magnesian limestone which overlies the coal affords an excellent stone for architectural purposes, and was a good deal used by the monks in the construction of some of their splendid specimens of Gothic architecture. This stone extends from Nottingham on the south to Sunderland on the north, where for several miles it borders on the coast: it is, therefore, readily attainable throughout a large portion of England; yet, notwithstanding its excellent quality, its present use is extremely limited. The coal grits, the gritstones underlying the coal, and other beds still lower in the series, afford excellent stones and freestones, and in the carboniferous and sition limestones and slates there are many beds ich would in all probability be highly serviceable to e architect. With so wide a range of architectural aterials as exists in Great Britain, there is, in fact, o excuse whatever for making a hasty and injudicious selection, and yet it is impossible to examine many of our public buildings, and find their exterior in a state of premature dilapidation and decay, without seeing that such has been the case.

British marbles.—Although perhaps, on the whole, the British ornamental marbles must yield to those of Spain and Italy, there are many of them but little inferior in beauty, while their comparatively small expense ought to recommend them to a far more general adoption than is actually the case. Some of the Devonshire marble is very rich in its appearance, and no person who has visited Derbyshire can be ignorant of the beautiful variety of marbles found in that county. Ireland also affords good specimens of this ornamental stone, of which the black Kilkenny marble is, perhaps, the best known. With such variety and abundance of native marbles before us, all attainable at a moderate cost, it is really surprising that so little use should be made of this mode of decoration both in public and private buildings, or that imitations should be used when the substance itself is so readily attainable. There is no respect, unconnected with difference in religious feeling, in which the churches of Catholic countries differ so much from our own, as in the profusion of beautiful marbles with which they are decorated. Were this mode of decoration to be practised in England, the interior of our churches would be greatly relieved of their present monotony, a wider scope would be given to architectural taste, and the use of a beautiful but neglected species of native produce would be much encouraged.

UNSTRATIFIED ROCKS CONSIDERED AS BUILDING MATERIALS.—The unstratified class of rocks affords several very valuable materials for architecture, but differing in many respects from those which have just been described, their general characters being a more perfectly crystalline texture, excessive hardness, and great durability. Granite (of which there are many different varieties), syenite, porphyry, and serpentine, all belong to the class under consideration. Stones of this kind (excepting the latter, which is merely ornamental) are peculiarly adapted for public buildings and monuments, for large and massive edifices, and for bridges. Their durability is almost unlimited, as may be seen in the perfect state of many of the ancient Egyptian monuments in the British Museum, which, after a lapse of three thousand years, are still in a state of excellent preservation: the circumstance, however, which limits their application, is their excessive hardness, and the consequent difficulty and expense of working.

GRANITE, SYENITE, &c.—Granite, as before noticed, is extremely abundant in Cornwall and Devonshire, in the north of England, and in Scotland, while syenite, porphyry, and serpentine are very generally found in the same localities. Both in quality and abundance the British Islands may compare with any similar tract on the globe as regards these fine and durable building-materials; but till within the last few years, the use of them has unfortunately been very limited. The texture of our granitic rocks varies much, affording varieties well adapted for almost every purpose of architecture or engineering, when the cost is not too great to admit of the use of this stone. The granites of Devonshire and Cornwall are generally coarse and porphyritic, and contain a large proportion of felspar; they are well adapted for all purposes where great finish is not required, but care should be taken not to employ any of the decomposed varieties, of which the extreme cases are in a state of complete disintegration. The Scotch granites are generally much finer grained and more compact than the former; they are, therefore, well adapted for purposes where finish is required, and are considered superior to the West of England granites in strength and durability. The Isle of Jersey also furnishes a fine compact red granite, which is pretty largely quarried. Syenite, which is generally classed by architects with granite, is also an excellent and durable stone; it is chiefly obtained from quarries at Mount Sorrell in Leicestershire, and is also abundant in Scotland. It is deserving of remark, that our most prominent masses of granite are generally well situated for water-carriage, a circumstance of great importance to the extended use of this material. Although the first cost must always be higher than that of other kinds of stone, where the future is at all taken into consideration, its great durability, and the consequent saving of expense in repairs, will go far to remove any objection to its use, on account of the first outlay. Thus in all public building, as durability is an essential point, granite may claim the preference even on the score of economy, while in point of appearance and fitness it has a decided advantage in all massive structures. It appears singular, indeed, that its use should not be more generally adopted in a country where it abounds so greatly; and, since we can afford to pave our streets with granite, it can hardly be considered too expensive for our public buildings.

FOUNDATIONS OF BUILDINGS.—The necessity for some knowledge of the substrata in all situations where buildings are to be erected, or which must serve as the foundation of bridges and viaducts, is too obvious to require comment; and, although actual excavation must always be had recourse to, geological information could hardly fail to be of much service on such occasions. There are many circumstances, indeed, calculated to affect the strength and firmness of a foundation, and consequently the durability of the superstructure, of which no person unacquainted with geology can form an adequate and correct idea. In cases where the precise locality is a matter of choice, geological considerations might, indeed, often afford the best grounds for selection.

CONCLUDING OBSERVATIONS.—It would be easy to extend this portion of the work to a much greater length, and to point out the value of geological knowledge both to the landed and mineral proprietor, the numerous applications which it admits of, and the loss and disappointment which have often resulted from the want of it. So many instances of the great utility of geological science, independently of the magnitude, the beauty, and the novelty of the views which it unfolds to the mind, have, however, been adduced in the course of this volume, that further observations would be almost superfluous. The reader who has attentively studied the foregoing pages will, it is presumed, have attained a thorough acquaintance with the elementary portion of practical geology; and, should he be desirous of still further extending his knowledge of the subject, the following observations will materially assist him, by pointing out the proper path to be pursued.

ON THE STUDY OF GEOLOGY, AND UTILITY OF GEOLOGICAL MAPS AND SECTIONS.

PRELIMINARY KNOWLEDGE.—The student who is desirous of acquiring a practical and thorough knowledge of geology must chiefly prosecute his studies by laborious researches in the great field of nature, and must there explore for himself the various phenomena presented to his view. His first step must be to understand, by reading, the leading facts and principles of the science, as they have been laid down in the present volume; he must learn to recognise at once the principal simple minerals entering into the composition of rocks, and also the various metallic ores, and other minerals, which usually occur in veins. He must likewise be acquainted, and the more minutely the better, with, at least, the more common forms of fossil organization, and with the general mode of their distribution, in the rocky masses constituting the crust of the globe; some preliminary knowledge of chemistry, although not perhaps absolutely essential, will form a very desirable addition to the qualifications already named.

LOCALITIES REQUIRING EXAMINATION.—Thus provided with the knowledge requisite to decipher the instructive pages, on which Nature has recorded in her own language the history and revolutions of our planet, the student may now commence the most valuable, but by far the most laborious, part of his career. He must visit the deep recesses of our mines, which, although too much neglected, afford the finest examples of many of the most important facts on which the science of geology is built. He must observe the strata, as laid open in our quarries, and as displayed in the deep cuttings of our roads, railways, and canals. Every excavation will indeed present something worthy of notice to his view; but, not contented with observing merely those spots where the labour of man has penetrated into the interior of the earth, he must wander around the base of the lofty cliffs which overhang the ocean, and observe the grand and instructive sections which Nature herself presents, and of which our own islands afford such numerous and admirable examples. He must pursue the course of rivers into the interior, and observe the strata laid open by the excavations of their currents; but his most instructive studies will be found, when he has arrived far inland, at the mountains, where they take their rise: here he will find that Nature has revealed the structure of the globe on the grandest scale; here the marks of ancient revolutions will be found imprinted in characters not to be mistaken, and the truth both of facts and theories, before known only by description, will at once be impressed on his mind. By researches of this kind extended over considerable tracts of country, so as to embrace all the great series of geological formations, and by careful study and comparison of all the phenomena presented to his view, both as regards the mineral structure of the globe, the forms of organised bodies peculiar to each species of rock, and the physical changes now taking place on the earth's surface, the student will at length become a practical geologist, and be enabled by his own observations to improve and advance the science he has been studying.

MOST SIMPLE MODES OF ACQUIRING KNOWLEDGE.—But the course which has here been pointed out, although essential to a practical and thorough knowledge of the subject, can only be pursued by few; yet a general idea of its most important facts, and the practical consequences arising from them, is of comparatively easy attainment. The great principles of geology have been most ably brought together in various publications, and, where only a general knowledge is required, geological maps and sections may be made in some measure to supply the place of travelling and observation. A few words, then, o those important documents, which are the mediu of expressing some of the most important practica results of the labours of geologists in the field, ma not be misplaced.

GEOLOGICAL MAPS.—A geological map combine with the geographical and physical features of a country a view of its internal structure. This peculia feature which, on a geological map, is so distinctly shown, it need hardly be observed is in nature completely obscured and difficult to trace, as verdure and vegetation, and a covering of loose superficial soil, almost completely obliterate, to the unpractised eye, whatever difference of the rocks and strata may exist below. In forming a geological map, we proceed, therefore, on the principle of all wood and vegetation being absent, and suppose that every species of superficial soil and covering is removed, so that the actual rocks and strata which compose the solid crust of the globe beneath shall be perfectly exposed, and laid open to our view. The space occupied at the surfac by these rocks and strata is then distinctly shown b different tints of colour, in the same manner as territorial divisions are indicated on ordinary geographical maps.

But, although we thus obtain a perfect view of th *surface* distribution of the solid materials of th globe, it is evidently no less essential to know in what manner they are arranged *below*, and what relations they bear to each other in the internal parts of the earth. This object is accomplished by means of geological sections, the nature of which will require but little explanation.

GEOLOGICAL SECTIONS.—A geological section supposes that, on any given line, the internal structure of the earth be laid open in the direction of a vertical plane. It therefore merely represents, although generally on a much more extended scale, the same thing which we see in many artificial excavations, and which Nature herself exhibits to our view in cliffs and precipices. Geological sections are indeed merely a combination of sections of this kind, to which they bear the same relation as the map of a large country would do to the smaller plans and sketches from which it was compiled; although, for the sake of distinctness, the vertical heights are always much exaggerated.

CONCLUSION.—From the sources which have now been pointed out, when rightly understood, much valuable information may be gained, more especially should the study of them be accompanied by the occasional inspection of a series of the more important rocks and fossils, such as may be seen in many collections and museums, both public and private. The observation of such geological phenomena as may present themselves in the ordinary progress of customary journeys or excursions may be made the means of adding greatly to the knowledge derived from the preceding sources, more especially should sketches be made and specimens be collected.

In this manner it is in the power of almost every individual to open for himself a new and interesting field of observation and research, to prove, as the poet has well expressed it, that—

> "Presented to the cultured eye of taste,
> No wild is barren, and no desert waste;"

while in many cases the knowledge thus acquired will be found capable of application to many very important and useful purposes, as must be readily apparent to the reader who has perused with attention the foregoing pages.

APPENDIX.

EXPLANATION OF THE TERMS MOST FREQUENTLY USED IN GEOLOGY.

Alumina, oxide of the metalloid aluminum; it exists largely in all clays, and, combined with sulphuric acid, forms sulphate of alumina, or common alum.

Alluvial deposits, or *alluvium;* aqueous deposits of sand, shingle, &c., produced by causes now in operation.

Ammonite, formerly called the "*Cornu Ammonis*," from its resemblance to the horn with which the statue of Jupiter Ammon was represented. A flat, spiral, many-chambered shell, found in great abundance throughout the oolitic strata. The shell is similar in its internal structure to that of the Nautilus. The fossil species are very abundant, varying in size from that of a sixpence to three or four feet in diameter, but it is now quite extinct.

Amorphous, possessing no regular or definite form.

Anoplotherium, an extinct animal not unlike the boar. It was discovered by Cuvier in the tertiary deposits of the Paris basin.

Anthracite, commonly called "stone coal," or "culm;" a species of coal composed almost entirely of carbon, and therefore burning like coke, without flame or smoke. It is abundant in South Wales, Ireland, and the United States of America.

Aqueous deposits, rocks or strata formed by the agency of water.

Axis, this term is used in geology to denote the central line either of elevation or depression of disturbed strata. An *anticlinal* axis is formed where strata are bent into the form of a ridge or saddle, like the letter V inverted, thus, Λ; a *synclinal* axis, on the contrary, is the line towards which the strata dip where an elongated depression occurs; thus, V.

Arenaceous, sandy.

Argillaceous, of a clayey nature.

Augite, a black crystalline mineral, abundant in lava and volcanic rocks.

Basalt, a pyrogenous rock which often occurs in natural columns, the result of a magnificent crystallization of the mass in cooling.

Basin, geologically, a series of deposits lying in a hollow or depression of the strata.

Basset, the rise of a bed to the surface, synonymous with *outcrop*.

Belemnite, a fossil abundant in the lias and oolites; it appears to have been a long cylindrical pointed shell.

Bed, a layer of rock.

Bitumen (hence bituminous), a soft inflammable substance, very appropiately termed "mineral pitch," probably resulting from the decomposition of coal.

Blende, sulphuret of zinc, a dark brilliant mineral.

Breccia, a rock made up of *angular* fragments cemented together.

Calcareous, a term applied to rocks or minerals containing lime.

Carbon, a simple combustible body: it is the basis of every variety of coal, of which substance it forms from seventy to ninety per cent.

Carboniferous, that which contains coal.

Carbonic acid, an acid best known as a gas, which is formed by the combination of carbon with oxygen. In a solid state it forms a large proportion of all calcareous rocks and minerals.

Chert, a hard silicious mineral often found in limestones and other rocks.

Chlorite, an alkaline mineral of a green colour.

Conglomerate, often called "pudding-stone," a rock composed of *rounded* fragments cemented together.

Crag, a provincial name for the most modern of British tertiary deposits.

Crop, or *outcrop*, a term expressive of the rising of a bed or stratum to the surface.

Crystal, and hence *crystalline*, a natural geometrical solid.

Delta, the sandy accumulations at the mouths of great rivers.

Diluvium, sand, gravel, and rolled masses of rock, which have been brought into their present position by causes no longer in action.

Dip, the angle of inclination formed by a stratum, a mineral bed or vein, with the horizon.

Dyke, a thin tabular mass of basalt or other trap-rock which cuts through the strata, dividing them like a wall.

Eocene, a term applied to the oldest tertiary strata, expressive of the small proportion of existing fossil species which they contain.

Fault, a dislocation in the continuity of the strata—a fissure filled with clay or abraded matter.

Felspar, a very abundant alkaline mineral, one of the constituents of granite.

Formation, a group of rocks possessing the same general characters, and apparently originating at the same period, and under the same circumstances.

Fossil, any organic body, whether mineralized or not, which is found buried in the crust of the globe. Most fossils belong to extinct species.

Galena, sulphuret of lead, its most abundant ore.

Gault, a blue marl which lies below the chalk.

Gneiss, a stratified rock, resembling granite in its composition.

Greywacke, an indiscriminate term applied to a great variety of ancient slaty and altered rocks.

Gryphite, a fossil univalve shell, having some outward resemblance to the Nautilus, and abundant in the oolites.

Gypsum, sulphate of lime.

Hornblende, a dark green mineral abundant in igneous rocks.

Icthyosaurus, a fossil reptile partaking the characters of the fish and lizard. Its remains are abundant in the lias and oolites, especially the vertebræ.

Igneous, as opposed to *aqueous,* rocks produced by subterranean fire.

Iguanodon, an enormous fossil reptile allied to the modern Iguana, and occurring in the Wealden deposits.

Laminæ, thin plates; slates are said to be laminated.

Lava, the most abundant and best known product of volcanoes.

Lias, a well-known argillaceous and calcareous deposit, lying below the oolites.

Lignite, fossil wood partially converted into coal.

Madrepore, a species of coral, abundant in the fossil state.

Magnesia, a well-known alkaline earth which forms an ingredient in some limestones and many volcanic rocks.

Mammoth, the fossil elephant.

Mastodon, a species of fossil elephant of great size.

Matrix; the sparry substance which includes the metallic ores; it is sometimes called the "rider," or "gangue."

Megalosaurus, an enormous fossil lizard.

Megatherium, a fossil animal of immense proportions, allied to the recent sloth.

Miocene, a term applied to tertiary formations, intermediate between the Eocene and Pliocene.

Mica, an alkaline mineral abundant in granite, also in the slate, thence called mica-slate.

Naphtha, or "mineral oil," a fluid inflammable mineral allied to bitumen.

Obsidian, or "volcanic glass," a greenish or blackish volcanic production, somewhat resembling common bottle-glass.

Oolites, secondary limestones, composed of small spheroidal particles, somewhat like the roe of a fish.

Orthoceratite, a conical-chambered shell found in transition rocks.

Paleotherium, an extinct animal like the boar, but of great size; it was discovered by Cuvier in the tertiary strata near Paris.

Petroleum, or "rock oil," a substance intermediate between bitumen and naphtha.

Plesiosaurus, an extinct amphibious animal, allied to the lizard, but of very extraordinary structure: like the Icthyosaurus, its remains are chiefly found in the lias and oolites, the period when these rocks were deposited having been characterized by the existence of numerous and extraordinary reptiles of the lizard tribe.

Pliocene, a term applied to the most recent members of the tertiary series, expressive of the large proportion of recent fossils; it is subdivided into older and newer Pliocene.

Porphyry, a generic term applied to all igneous rocks which contain imbedded crystals in a homogeneous mass.

Primary, the class of rocks destitute of organic remains, and imbedded fragments; formerly called *primitive.*

Producta, a fossil bivalve shell, abundant in the mountain-limestone.

Pyrites, combinations of the metals with sulphur.

Quartz, the oxide (or acid) of the metalloid silicium; it is a constituent of granite and very abundant in the older rocks. In secondary strata it appears as sandstone, sand, and flint.

Rock, applied in geology to express any of those mineral masses of which the globe is composed.

Schist, a German word synonymous with slate.

Secondary (as opposed to Primary), derivative rocks containing organic remains of extinct species, and imbedded fragments of older rocks.

Septaria, nodules of argillaceous limestone found in the London clay.

Serpentine, a greenish variegated rock of the unstratified class.

Shale, a soft species of slate, abundant in the coal-measures.

Silica, the pure oxide (or acid) of silicium.

Spirifer, a remarkable bivalve shell, occurring in the mountain limestone and other transition rocks.

Stratum, a bed, or layer of rock.

Strike, of strata, synonymous with their bearing or direction.

Syenite, a variety of granite containing hornblende instead of mica.

Tertiary, a name applied to those sedimentary rocks which contain fossils of existing species. In the regular order of superposition, they follow the secondary rocks before noticed.

Transition, an indefinite term applied to the oldest secondary rocks.

Trap, a term applied by the earlier geologists to many unstratified rocks, as basalt and greenstone. It is derived from a Scandinavian word, signifying a step or stair. Rocks of this class frequently present an irregular outline, not unlike steps or piles of ruins.

Tufa, a volcanic conglomerate.

Veins, those thin tabular masses of sparry and metallic matter which frequently intersect rocks, and form the principal depositories of the metallic ores, especially tin, copper, zinc, lead, and silver.

Veinstone, or "*vein stuff*," the sparry matter forming the great bulk of all mineral veins, and inclosing the metallic ores.

Volcanoes (sometimes very improperly called burning mountains), a name applied to those orifices, generally on the sides or summits of mountains, which communicate with the interior of the globe, giving vent to incandescent matter and various gaseous products, the results of intense chemical action.

Zoophytes, a class of animals having no powers of locomotion, and in some measure resembling plants, being rooted in the bed of the sea. Recent corals and sponges belong to this class, which attained an immense development in the fossil state, many thick and extensive strata being chiefly formed by their remains.

REFERENCE TO THE PLATES.

PLATE I.

Index-Map of the Geology of the British Islands.

This map has been constructed to illustrate some of the more important features in the geology of the British Islands, and will form a convenient index to larger and more elaborate works of the kind. It has been already referred to in the body of the work, but will perhaps be more readily understood from the explanation here given.

The portion of the map distinguished by the letter *a*, and shaded by horizontal lines, shows the extent of the tertiary formations of England, or those lying above the chalk. The position and extent of the London and Isle of Wight basins will thus be at once perceived.

The portion coloured yellow, and marked *b*, comprehends the chalk, together with the subjacent oolites and the lias. The small subdivision marked $\underline{b}$ shows the extent of the interesting series of rocks called the Wealden formation, which is only recognised in the south of England.

The portion of the yellow tint marked *c* shows the area covered by the rocks intervening between the lias and the coal-measures, or the new red sandstone and magnesian limestone. The greater part of this tract is occupied by the former rock. The blue tint, marked *d*, shows the extent of the carboniferous system of rocks, comprehending the coal-measures, the subjacent millstone grit, carboniferous or mountain limestone, and old red sandstone. The upper portion of this mass, or the coal-districts, are distinguished by a dark shading.

The red tint, marked *e*, shows the extent of the vast mass of primary and transition slates, which lie beneath the coal; it includes, therefore, the greywacke slate, transition limestone, and primary clay-slate, with all their varieties, as well as the protruded masses of greenstone, syenite and granite, s abundant in this series of rocks. The scale of the map doe not allow the position and extent of these masses to be shown they will, however, be seen on reference to the body of the wor

PLATE II.

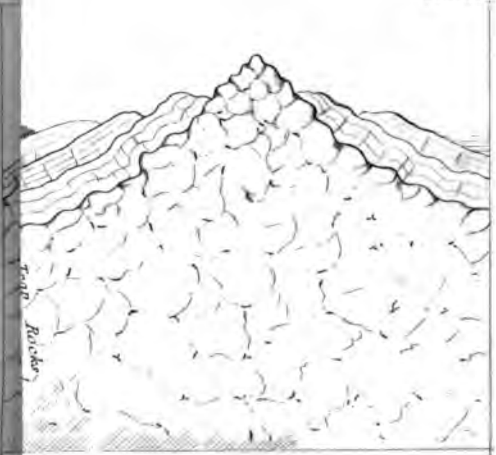
Fig. 1.—*General arrangement of the great classes of rock* Fig. 2.—*Mineral veins.* Fig. 3.—*Coal-basin dislocated by fault*

Fig. 1 shows the order of superposition of the great classe of rocks generally termed primary, transition, secondary, an tertiary, and also the relations of the stratified and unstratifie series of rocks. It has been already referred to, and describe at length, in p. 110.

Fig. 2 illustrates the nature of mineral veins and the displacement of the strata which they generally occasion in stratified districts, where the same beds are usually found at different levels on the two sides of a vein. Mineral veins, it will be recollected, are thin tabular masses composed of quartz, calcareous spar, fluor spar, barytes, &c., throughout which the ores of the metals are dispersed in "bunches" or irregularly-shaped masses. Their extent, either downwards or in the line of their direction, is great and indefinite, having perhaps in no case been satisfactorily ascertained, but their width is inconsiderable, seldom exceeding a few feet or yards. Their inclination to the horizon, termed in Cornwall the "underlie," and in the North of England the "hade" of the vein, is generally very great, approaching a perpendicular to it. The plate represents a group of veins or "lodes" seen across the line of their direction, and therefore exhibiting both their thickness and inclination. Veins often branch out from one another, or are crossed and dislocated by other veins having a different dip or direction, as shown in the plate.

Fig. 3 represents a section of the carboniferous system of rocks, where the series is most perfectly developed, and includes the subjacent millstone grit with the limestone shale and carboniferous limestone. The group of rocks of which

Plate 2.



l Basin dislocated by Faults.

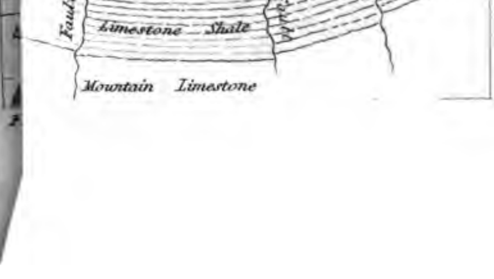
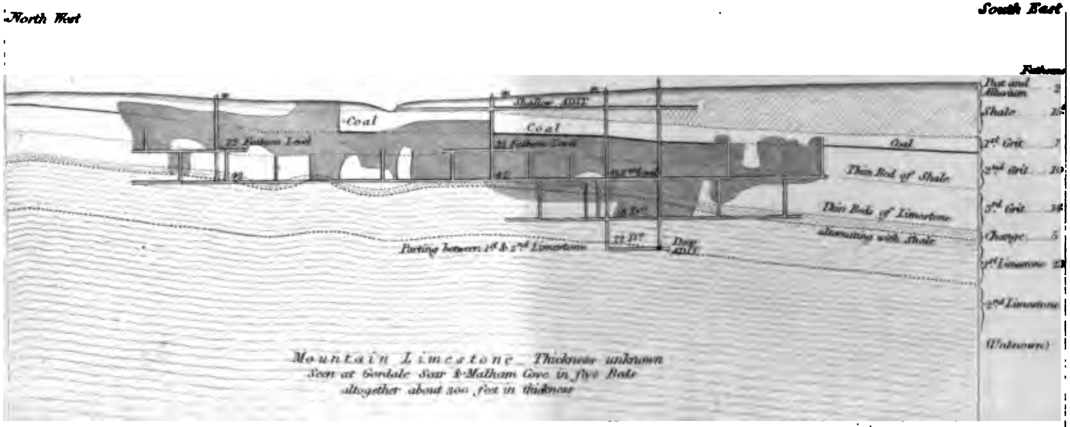


Plate 3.

Geological Section of Coalgrovebeck Lead Mine Yorkshire



E. Burr Delt.

the subdivisions are here shown is the one marked *d,* and coloured blue in the index-map. The most important beds of coal are contained in the upper portion or the "coal-measures:" they are indicated by strong lines, and, with the adjacent strata, are frequently disarranged and broken up by "faults," as shown in the plate. The coal-strata are generally found lying in extensive troughs or depressions of the strata below them, as seen in the figure.

PLATE III.

Geological section of Coalgrove Beck Lead-Mine, Yorkshire.

This plate gives an actual section of the junction of the millstone grit and carboniferous limestone in the North of England, and also shows the working of a lead-mine in these strata. In all mineral countries there are particular strata, or channels of ground which are most favourable to the production of the metallic ores, and it is chiefly while passing through them that the veins become enriched, or contain those *bunches* of ore before described. This great principle is well illustrated in the plate, where it will be seen that the excavations for obtaining the lead-ore have been almost entirely confined to the gritstone-beds, scarcely penetrating either the shale above, or the great mass of carboniferous limestone below. It is deserving of remark that, in mines similarly situated to the one in question, the gritstone-beds are generally most productive, although in Alston Moor and the adjoining mineral districts of Weardale and Teesdale, where the carboniferous limestone is much interstratified with gritstone and shale, it is certain beds of the limestone, and more especially the one called the "great limestone," which is most productive of ore.

A good idea may be obtained from this plate of the general mode of working mines. It will be seen that access to the vein is obtained by perpendicular pits or "shafts," and that at certain intervals passages or galleries, generally termed "levels," are excavated *upon* the vein, by means of which its mineral contents are explored. The portions of the vein between the levels are also explored at certain distances by small underground shafts termed "winzes," and the whole of the vein being thus laid open in large rectangular masses, excavations are then commenced upon those portions which contain sufficient ore to pay for working.

PLATE IV.

Geological section of the Consolidated Mines, Cornwall.

This plate gives a general section of the Consolidated Mines near Redruth in Cornwall, and affords an excellent illustration of the geological position of the most productive mines in that county, which, as already described, are situated near the junction of the granite and the slate. At the western extremity of the mines the mass of granite which forms the prominent hill called Carn Marth, dips below the surface at an angle of about 30°, and is overlaid by the metalliferous clay-slate, termed in Cornwall "killas," which is itself traversed by the porphyritic rock termed "elvan." All these rocks are intersected by mineral veins or "lodes," which are highly productive both of copper and tin, but more especially of the former metal. The veins have mostly a direction nearly east and west, and a dip or "underlie" to the north, and are intersected at right angles by barren veins or "cross-courses" chiefly filled with quartz and clayey matter. Their chief produce is the sulphuret of copper termed "yellow copper-ore," from which the great bulk of that metal is in most parts of the world obtained. The general width of the veins is from two or three to five or six feet, and, although large portions are filled with quartz and worthless matter, the bunches of ore have been aggregated together in masses of enormous size and richness. Their position and extent is shown in the Plate by the shading, which represents the vast series of excavations by which the ore has been obtained. The position of the shafts and levels upon the principal veins has also been shown, but the scale does not admit of noticing the innumerable winzes by which the veins are traversed.

The Consolidated mines are the most extensive in the world.

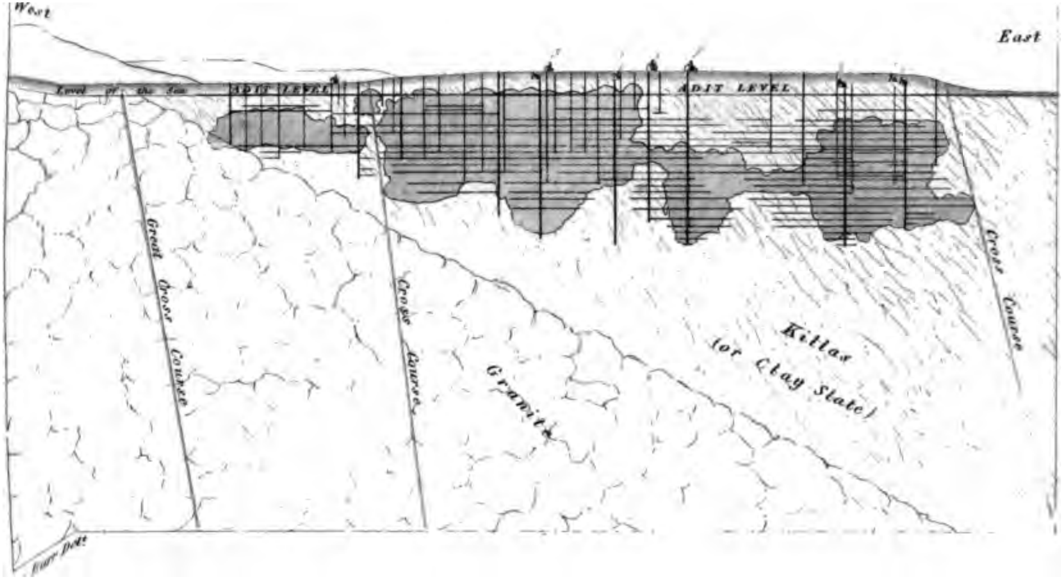
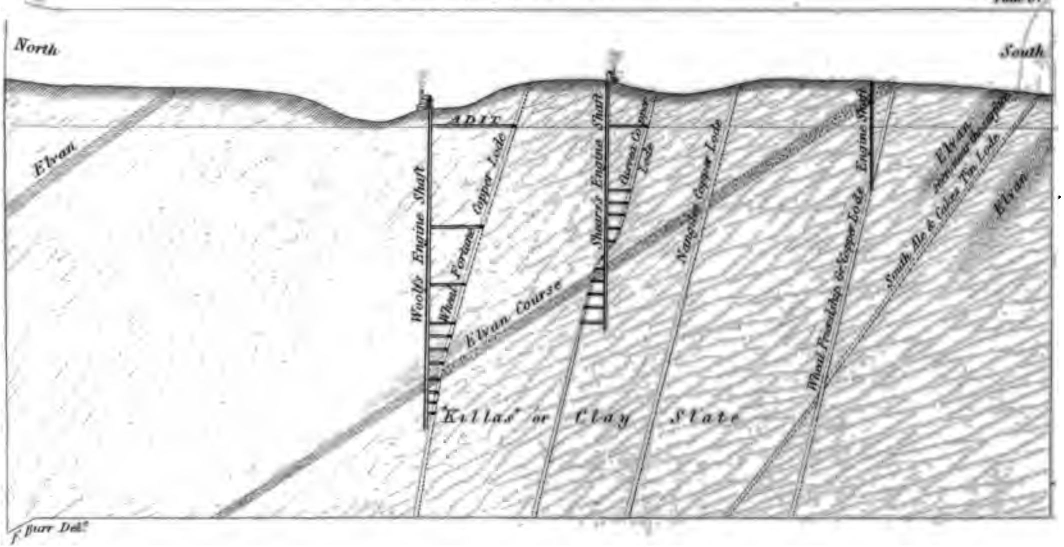

West
East
Level of the Sea
ADIT LEVEL
ADIT LEVEL
Great Cross Course
Cross Course
Granite
Killas
(or Clay Slate)
Cross Course

Plate 5.

Transverse Section of the Lodes and Elvan Courses &c. in the Eastern part of the Consolidated Mines.



Their extreme length is nearly two miles, and their greatest depth nearly 300 fathoms or 1800 feet. The drainage and extraction of the ore is performed by an unparalleled accumulation of steam-engine power, and about 3000 persons are employed upon the concern, which may be regarded as the greatest monument of mining skill and enterprise which has ever been produced either in this or any other country.

PLATE V.

Transverse section of the Consolidated Mines.

This plate gives a transverse section of the Consolidated Mines, near their eastern extremity; it shows the inclination of the veins, the position of the shafts with regard to them, and the mode in which the channels of porphyritic rock appear to traverse the slate. In some cases they have been ascertained by the workings of the mines to form tolerably regular (injected) beds, or "floors," considerably inclined to the horizon; in others, they have more the appearance of scattered undefined masses, irregularly protruded from below. Some of the "elvan courses" shown in the plate have never been traced to any great distance below the surface, and are therefore not continued in depth. The position of the shafts with regard to the veins is here clearly shown, and also the "cross-cuts" or small passages by which the communication is effected, either before the shaft has cut the vein or after it has passed perpendicularly through it. By comparing the *transverse* section given in this plate with the *longitudinal* one in Plate 4, a much clearer insight will be obtained into the system of excavations by which mines are formed. It must however be borne in mind that the scale of the latter is greater than that of the former, and it may further be observed that in the western part of the mines the number of lodes, and smaller veins or "branches," is much greater than in the eastern, and the workings therefore much more complicated, the same levels being driven upon several parallel veins and branches, and communicating both with the shafts and with each other by means of numerous cross-cuts. A better idea of the extent and magnitude of underground operations in these celebrated mines, and of the energy and perseverance with which the works have been carried on by the present Company, can hardly perhaps be given, than by stating that, in a period of scarcely twenty years, underground operations in "sinking" and "driving" mostly in the solid rock, for the sole purpose of discovery, have been executed to the extent of more than 55,000 fathoms, or about *sixty-three miles*, at an expense which cannot have fallen short of 300,000*l*.

PLATE VI.

Remarkable forms of Fossil Organisation.

This Plate will give a general idea of a few of those remarkable fossil forms with which the student should early become acquainted, and in the study of which, more especially as regards the nicer distinctions of species, little progress can be made without reference to characteristic specimens, which he should therefore endeavour to collect.

The following are the fossils figured in the Plate :—

Fig.	
1	Echinus.
2	Fusus.
3	Pecten.
4	Ammonite.
5	Belemnite.
6	Gryphite.
7	Terebratula.
8	Producta.
9	Spirifer.
10	Encrinite.
11	Orthoceratite.
12	Trilobite.

It may be observed that the Echinus, Fusus, and Pecten, are common in the London clay and chalk, the Ammonite, Belemnite, and Gryphite in the Oolites, while the Terebratula, Producta, Spirifer, and Encrinite, are abundant in the carboniferous limestone, and the Orthoceratite and Trilobite are especially characteristic of the transition limestones.

Plate

Remarkable Forms of Fossil Organization.

Fig. 1.

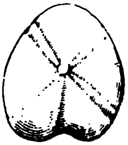


Fig. 2.

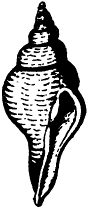


Fig. 3.

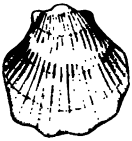


Fig. 4.

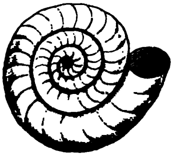


Fig 5

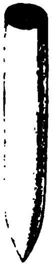


Fig. 6.

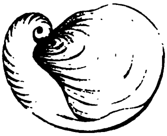


Fig. 7.

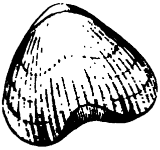


Fig. 8.

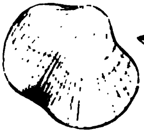


Fig. 9.

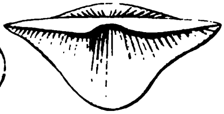


Fig. 10.

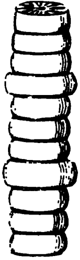


Fig 11.

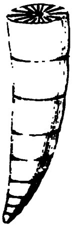
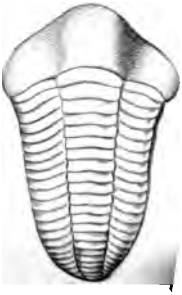


Fig. 12.



E. Burr Del.t

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laid down, chiefly from original observation, the position hose portions of our strata which are known to contain der a clear and general view of the geographical position, of our mineral produce, it must be observed that the onsidered as *approximate only*, although the result of

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onsiderable .	Only locally used for fuel.
00,000 . .	Independently of home consumption, a very large quantity of Salt is exported.
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